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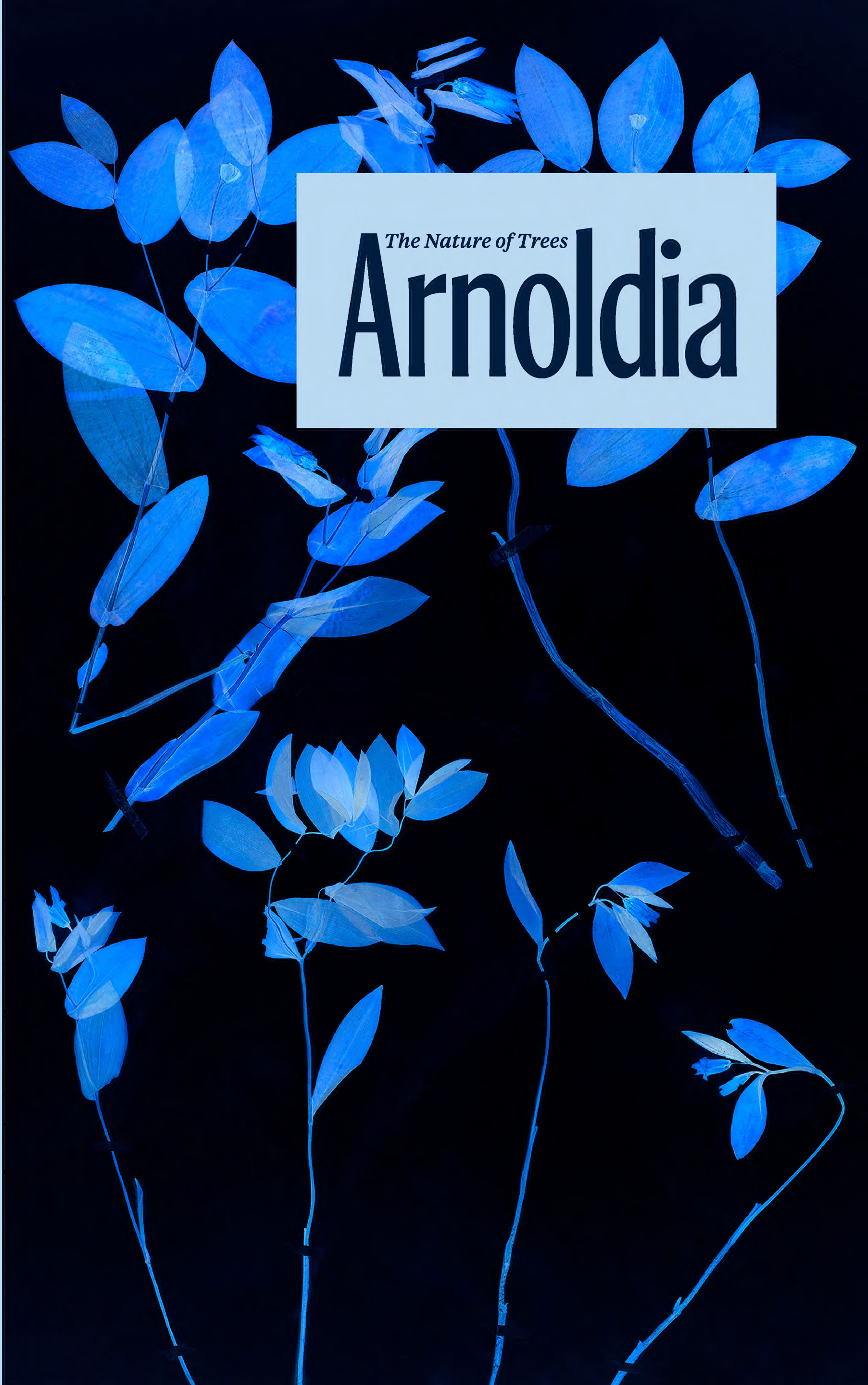

The Nature of Trees

Arnoldia

Perspectives on Extinction and Botanical Collections

From Extinction to Emergence

By Matthew Battles

When I type "American" into my browser's search bar, it autocompletes with "chestnut." Considering all the other words that could appear after "American" in a search, "chestnut" feels like a kind of victory—even if it's Pyrrhic, given *Castanea dentata's* critically-endangered status. When I moved to New England more than a quarter century ago, I understood the species to be "functionally extinct"; I've since learned that this was a simplification at best. But I had no idea how uncanny their existence would prove to be. Although the blight still takes out mature trees as they bear fruit, young wood thrives for a few years before the disease sets in. I love catching sight of the bladelike leaves of a relict chestnut in the woods, the live sapling keeping company with the older, taller stems the roots have sent upward, each to die back in turn as the blight catches them, until they stand in a splayed sheaf like so many walking sticks in an umbrella stand.

The American forest has been decimated and come back; today, it includes new plants in new relations. Chestnut enthusiasts are turning to hybridization and even genetic engineering in hopes of restoring the tree to recollected glory. But I wonder what it means to try bringing back this former forest. Those ghost chestnuts, meanwhile, bide their time in the woodlots and urban wilds, waiting for the blight to burn itself out—waiting to build a new kind of forest. What kinds of new complexity, what forms of emergence, do the visions of de-extinction discount?

I thought of those ghost chestnuts last year while visiting Maui, where I had traveled to visit the home and palm garden of the late poet W. S. Merwin. I also had a very different extinct plant in mind—a species endemic to Maui, which in a way went extinct *twice.* When he first identified it in 1910, high on the slopes of Haleakalā volcano, botanist Joseph Rock found only three living trees of the branching lobelia he called *Clermontia haleakalensis.* "It will not be long before they will have shared the fate of so many of our native trees," he observed, "becoming extinct, as cattle have free access and browse on the lower branches within their reach." Rock's pressed collections are the only known remnants of the plant. More than half a century later, another investigator reviewing these vouchers determined that the plant was not in the genus *Clermontia,* renaming it *Cyanea pohaku* (the specific epithet means "rock" in Hawai'ian): a second species, but one born into extinction.

Driving the road to Haleakalā's summit today, the landscape still is a vast, lifting grassland dotted with steers, partitioned here and there by dark-green clusters of introduced pines and eucalypts planted to develop commercial forestry on the island's cattle-denuded landscapes, where endemic forests of spectacular complexity and distinctive biodiversity had previously thrived. This failed scheme was devised by Ralph Hosmer, a key figure in the nascent U.S. Forest Service, who wanted quick-growing tropical trees to kickstart a timber industry in the archipelago. To identify and source the trees, he hired Joseph Rock.

Who knows what else is brewing in the islands' fermentory of biodiversity?

Everywhere, extinction haunts Hawai'i. In the grove named for Hosmer in Haleakalā National Park, a stand of the gum trees he introduced gives way to a fringe of endemics, like *ʻōhelo ʻai* (*Vaccinium reticulatum*) with its cranberry-like fruits, beloved of the *nēnē* or Hawai'ian goose; and *ʻōhiʻa lehua* (*Metrosideros polymorpha*), the myrtle tree, blossoming in firework bursts of bright stamens. We watched among these for the *i'iwi* or scarlet honeycreeper, a vermillion droplet of a bird, its down-curving beak adapted to feeding from the lost lobelias. Its call came through the *ʻōhiʻa* like rusty hinges falling into water. I crept through the mix of native and introduced trees, entranced afresh by this yearning for a sign, a song, by this hope for an encounter to mend the broken world. Of course, the forces that extirpated *Cyanea pohaku* and so many other Hawai'ian species will not be stayed by a flash of red in a forest. Nor are such sightings all that is at risk. The denuding of west Maui's landscape, and the subsequent collapse of agriculture, laid the groundwork for the deadly fires that devasted Lahaina last year.

Farther to leeward across Haleakalā, the Auwahi Forest Restoration project nurtures a growing tract of Hawai'ian dryland forest, which persists as single plants and caches of seed, as quiet tangles in places the cattle can't reach. Landowners and community members are collaborating to kindle their lively relations anew. They're after something very different from Hosmer and Rock's quick, commodity-driven afforestation. This is slow, intergenerational work, building community among plants and people. The plant guild of this distinctive biome is missing many members (though I like to hope that, like the American chestnut, even *Cyanea pohaku* and some of its extinct relatives are biding their time as seed buried in volcanic soil somewhere on Haleakalā's vast flank). And who knows what else is brewing in the islands' fermentory of biodiversity? Last year, a new species of montane lobelia, *Clermontia hanaulensis,* was identified in the highlands of west Maui, high above the fire-devasted lands. Palms propagated in the poet's garden, meanwhile—in particular, hybrized *loulu,* or Hawai'ian native palm (*Pritchardia* spp.)—may someday help bring forests to Lahaina.

This issue of *Arnoldia* is the fruit of almost two years of conversation among scientists, artists, humanists, and horticulturists. We started with a simple question: *why aren't we talking about plant extinction?* We were hosted by Yota Batsaki at Dumbarton Oaks and Peter Crane at Oak Spring Garden Foundation, and I'm grateful for their generous leadership—and for their contribution to this issue as well. As Yota and Peter magisterially lay out the question in their essay ("Collections, Extinction, Abundance," page 20), plants do extinction differently from animals. They go into retreat as seed and root, or hole up in the corners and cupboards of the landscape; some find purchase in our gardens. We carry their memories in our bones, their questing, flourishing wont in our blood. The varied responses to the question of plant extinction in the pages of this issue follow the ways of storytelling, cultivation, biology, and artistry; they also well up from desire, memory, and hope. These make a refuge for us all.

MATTHEW BATTLES *is editor of* Arnoldia.
You can support Lahaina's renewal through the Maui Strong Fund (hawaiicommunityfund.org); to help the Auwahi Forest Restoration Project, visit auwahi.org.

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—Carl Scovel, longtime member

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A garden favorite from a lost world: *Franklinia alatamaha*, extinct in the wild. *William Bartram, 1788. Courtesy of the Natural History Museum, London.*

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Cover
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Back: *Oclemana acuminata* (Whorled Wood Aster)
Art by Leah Sobsey

Inside front and back covers
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Arnoldia
The Nature of Trees

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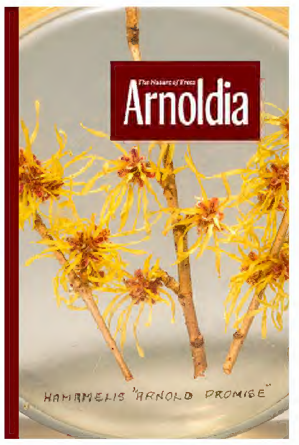
LETTERS



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In Memoriam

Our dear father, Dorick "Sonny" Corbo, a dedicated member of the Arnold Arboretum for over 45 years, passed away on January 11, 2024, at the age of 96. We believe his life's purpose, and one of his greatest gifts to the world, was to share his love and passion for trees and shrubs. The Arboretum played such a big part in this, and I am honored and grateful to share on his behalf.

The Arboretum is the scene of some of our earliest childhood memories. Many Saturdays, we'd ask our mother, "Where's dad?" Her response could be, "Oh, he's taking a class about pruning," or "He's on a tour with Peter Del Tredici about the ginkgo tree," or "He's at the member's plant sale." We can still see him pouring over books by Donald Wyman or Michael Dirr at our dining room table. Our yard was beautifully landscaped thanks to all he learned at the Arboretum—the pièce de résistance being our ginkgo tree, which grew to over forty feet.

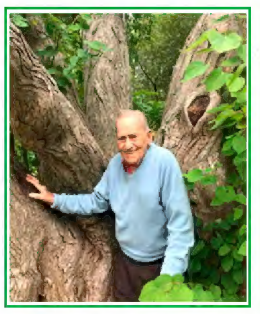
Our family spent countless Sunday afternoons visiting the Arboretum. My brother and I would run from the entrance gates past the Hunnewell Building, climbing the first hill we saw. Meanwhile, my father would be visiting trees and shrubs, reading each tag and deciphering the Latin botanical names. It was so special to watch him connect with all their beauty with such deep reverence and respect. It was like he was visiting old friends.

Throughout my adult life, I always looked forward to getting beautiful notes he had written on Arboretum postcards—often giving me words of encouragement or a message of hope that things would be starting to blossom at the Arboretum.

It was only recently that our father became unable to take classes or walk around the Arboretum. Even then, he

maintained his connection through his subscription to *Arnoldia*. Throughout his many moves from his house in Weymouth to assisted living to a nursing home, back issues of *Arnoldia* made the cut through all the downsizing. His wonder and love of horticulture never left him, which was so evident in his excitement over receiving the December issue.

Since his passing, so many people have shared stories about the plant or shrub he gave them from one of the Arboretum's plant sales and how he planted it for them and provided unlimited maintenance



advice. So many expressed that whenever they look at a tree, they recall his joy and passion and that whenever they drive by the Arboretum, they fondly think of him.

Our father was a quiet and selfless person who would never think to be mentioned in a subject written in *Arnoldia*. We do believe though, that where he is now, he is proud and humbled to continue being a part of the place he so loved, which in turn let him give joy to so many.

With much gratitude,
Teresa and Rosalie Corbo

CONGRATULATIONS

to

RACHEL MAY

whose article

"The White Oak Tree at MacLean: A Case of Recovery"

Arnoldia • WINTER 2023

was selected for

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Notes from the Field

The Cactus Chronicles

On the hunt for a contested succulent, **Jared Margulies** probes abundance and extinction with cactus hunters in Bahia, Brazil.

Jared Margulies is an assistant professor in the department of geography and the environment at the University of Alabama. His first book, *The Cactus Hunters: Desire and Extinction in the Illicit Succulent Trade,* was published by the University of Minnesota Press in 2023.

I am several days into a multi-week trip in the states of Minas Gerais and Bahia, Brazil, with a group of European cactus and succulent enthusiasts, as part of my research into the global illicit succulent trade. I was invited to join the group to better understand collector activities and desires that circulate around their encounters with plants. Above all, we are in Brazil to see its dazzling biodiversity of cacti. Today, we are in Bahia to visit several localities of *Melocactus azureus,* a species known for its gorgeous matte-blue skin and round form, topped with a red and white cap known as the cephalium.

Melocactus azureus is listed on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) as an Appendix II plant, but the collectors I am with think it is a CITES Appendix I plant—and they have strong opinions about this confusion. Appendix II of CITES allows regulated trade in listed species with appropriate national export permits (which can be difficult to acquire), while Appendix I is reserved for those species in which legal trade is effectively banned to control the impact of wildlife trade on species endangerment. Appendix II poses challenges for collectors to legally acquire desirable plant material, but Appendix I makes legal acquisition far more difficult.

Tom, a Dutch collector, says that the last time they were at this location, they found ten new populations with abundant numbers of plants, which isn't reflected in either the International Union for the Conservation of Nature (IUCN) Red List of the species—which classifies *M. azureus* as

Illustrations by Matt Huynh

Endangered—or its CITES listing as Appendix I. Milton, the Brazilian botanist serving as a guide on the trip, repeatedly explains to Tom that although the population *here* is abundant, the species is extremely restricted in extent, leaving it vulnerable. Milton thinks about abundance across geographic and temporal scales differently from Tom, who seems mostly preoccupied with the abundance as reflected in the number of individual plants he can observe. Tom argues there are millions of individual plants found across its range. "Why can't we celebrate that?" Tom asks Milton. "It's good," Milton replies, "but one development and they could all be wiped out." For Milton, abundance would seem to demand what I imagine as genetic and ecological redundancy across populations at a greater, regional scale. He has seen examples of seemingly abundant populations erased by rapid developmental activities.

Although the population here is abundant, the species is extremely restricted in extent.

Our first stop of the day is one of the oldest known locations for *Melocactus azureus,* but now, there are only a few plants. "It used to be a relatively large population, but it was collected, but also people chopped it up and fed [it] to cattle," Milton tells me. Tom seems defensive at this remark about over-collection. "You say that, but how long have people been assessing populations?" he replies. "Well, this is based on historical accounts of other collectors," Milton says.

We search for plants for a while, without success. "This is a typical example of an endangered population—we found two plants here ten years ago," Milton says. Rob, another British collector and enthusiast searching nearby, thinks he's found a specimen. The plant isn't very blue, but it does have a well-developed cephalium. As a novice, it looks to me like any other *Melocactus* that we've seen on the trip. Milton does not believe it is *Melocactus azureus.* This is another well-described, well-loved locality now absent a member of its collective ecology.

When I catch up with Milton, he explains that we are now headed to the type locality for the species—the location where a physical plant was collected and placed in an herbarium as the species type. All plant

BRUCE KIRCHOFF

CULTIVATING CONSERVATION

Saving the Boynton Oak

One of North America's rarest oaks can be found in the most unassuming (and inhospitable) landscapes imaginable. The sandstone glades of southern Alabama are home to the Boynton Oak (*Quercus boyntonii*)—an elusive, semi-evergreen, rhizomatous shrub. Despite treacherous terrain and oppressive heat, a group of conservationists from Huntsville Botanical Garden (HBG) have been leading the effort to learn more about—and preserve—this tree, as well as the myriad other life-forms that are connected to it. While the Boynton oak was once known in only four counties, it has now been identified in nine counties, and the overall tree count has risen from 300 to more than 1,000. Its variable growth pattern, from tall and tree-like to low growing and shrubby, has provided some challenges in its identification. The team at HBG has been using diverse approaches to safeguard the future of the Boynton oak, from distributing the tree's acorns, to connecting with landowners who have specimens growing on their property, encouraging them to care for these special trees.

species have a type specimen somewhere in the world in an herbarium; until they do, they cannot be formally recognized as a species. "There will be a few more plants [there], but it's now next to the city of Jussara and it is a garbage dump. It will disappear soon," Milton says.

After a drive, we arrive at the dump site, just on the edge of town. Visiting a type locality with passionate plant people often lends gravitas and importance to the place, distinguishing it from other locales. The visit to a type locality represents a kind of collecting encounter with the place tied to the *genuine article*—the species type. And yet what we saw before us felt nothing like what I had imagined. The locality served as an informal dumping site and was covered in trash. Many cacti were present, but many were also entangled in plastic bags. I had been mistaken in imagining that a type locality somehow offered a plant a degree of formal protection.

I had been mistaken in imagining that a type locality somehow offered a plant a degree of formal protection.

"I don't know whether to be impressed or depressed, but Peter went out and said he looked through the mess and saw lots of young plants," Thibault, a Belgian collector, says to me as we stand together looking at the landscape. Thibault adores *Melocactus,* and so I ask him if he is happy to see so many plants despite the state of the landscape. "There are never enough *Melocactus* for me!" He replies happily. I ask him if he has found any plants bearing fruit. He has, he replies, and he will take these home to Belgium. In Brazil, this is illegal. At the same time, it is seen as socially acceptable to the collectors I am travelling with in a way that removing a living plant from the ground would not be. For them, the taking of small quantity of seeds is seen as a way to ensure other people can grow and reproduce the plants they desire in a way that does minimal harm to wild populations. But other scientists disagree, and today in Mexico, the country with the greatest species richness in cacti, even cactus seeds require CITES Appendix II export permits.

Milton notes that his waypoint for the type specimen is 200 meters in the other direction, where we see houses built at the edge of town. "Jared, take a picture of the houses," Milton says. "That is what is coming. My original waypoint for this location doesn't exist anymore. And soon they will start building here where we are standing." Based on his coordinates, the original type locality is now part of the village. Some in the group are happy to see so many cacti, but for others it is hard to feel optimistic about their fate, covered in plastic bags on the edge of a slowly growing village.

After spending an hour weaving our way through the population to take photographs of plants, we drive to a more recently described locality teeming with plants—easily tens of thousands or more. By now, it is well over a 105 degrees Farenheit and the sun is beating down.

Amidst this abundance of plants, Tom is keen to demonstrate to me how well the species is doing from a conservation standpoint. "Look how many seedlings there are, Jared ... more than [even] last time I think." Milton, who is standing with us, disagrees. He explains that all the mature plants we see are a few decades old, and it takes one to two decades for the species to reach maturity. Tom turns back to me. "This place deserves to have its story told loud and clear and everywhere." Tom believes that it is unreasonable for the plant to be listed on CITES and classified as Endangered on the IUCN Red List. For him, it delegitimizes the scientific authority of these programs, and points to a more fundamental issue: the lack of recognition of botanical expertise among the amateur cactus and succulent hobby community.

"(W)hy do these assessors get to give it such a lukewarm assessment?" Tom says, turning to Milton in frustration. "Because there are no herbarium specimens [for the locality]," Milton replies. This population essentially doesn't exist in the realm of conservation knowledge. "Well I think it *stinks,*" Tom says, frustrated. He continues, "Why won't they come and do the assessment?... I just feel it is a lie. And I feel it personally because I'm not a trained botanist ... I'm afraid I've always perceived a certain arrogance among the profession, and I think it's a great shame, and I will work hard to fight that. Thibault, can you do an article in *Grusonii* about this place? Because Milton is saying that by no means have the assessments taken these kinds of places into account." Thibault says he would be happy to publish about it in multiple outlets.

"I want the truth to be known from the organization that is supposed to be bringing me the truth," Tom says. "By all means send a verifier if need be but I am going to make sure the *truth* gets out."

As tensions rise, the conversation is cut short by a sudden yelp from another collector on the trip, Chris, who has been stabbed in the foot by a cactus spine.

In this encounter with a species of cactus in Brazil that, depending on whom I asked, was either threatened or thriving, key tensions and questions of expertise and scientific knowledge came to a head. For many of the collectors I travelled with, the appearance of abundance led to frustration that scientists still considered the plant endangered, when instead they hoped to share stories of promise and conservation success. For them, this apparent contradiction reinforced feelings that their expertise was not valued. I suspect that, alongside these contests over expertise, collectors also felt that the refusal of scientists and conservation authorities to recognize abundance reinforced the idea that over-collection was a cause of species concern, framing amateur collectors as conservation villains.

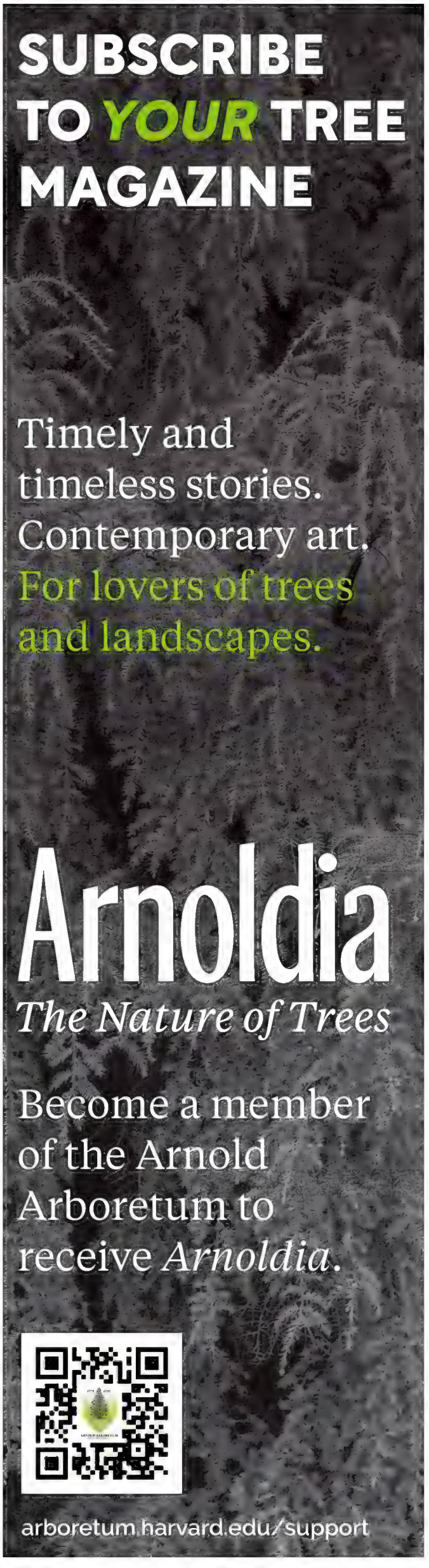
I went to Brazil to understand these often-fraught relationships pitting the

HARVARD UNIVERSITY HERBARIA

SENSORY ECOLOGY

Resurrecting the Sublime

Resources such as drawings, photographs, and herbarium vouchers allow us to visualize what now-extinct plants looked like whilst they flourished. But what might these plants have smelled like? *Resurrecting the Sublime*—a collaboration at the intersection of art, scent science, and biotechnology—attempts to answer this question. Using minute amounts of DNA extracted from herbarium specimens at the Harvard University Herbaria (including the Arnold Arboretum), scientists at Ginkgo Bioworks used synthetic biology to "resynthesize gene sequences that might encode for fragrance-producing enzymes." Artist Alexandra Daisy Ginsberg and smell researcher Sissel Tolaas used these findings to reproduce the former flowers' smell, using identical or comparable molecules. Appearing in several interactive installations since its premiere in 2019 at the Centre Pompidou in Paris, Resurrecting the Sublime is currently on view at the MIT Museum, as part of their Gene Cultures exhibit. There, visitors may catch a whiff of Falls-of-the-Ohio scurfpea (*Orbexilum stipulatum*), last seen in 1881. Other displays include scents of *Hibiscadelphus wilderianus* and *Leucadendron grandiflorum,* both extracted from the Arnold Arboretum Herbarium.



In these fantasies of abundance and extinction, the ecology of the plants felt profoundly absent.

formal and scientific community against the cactus and succulent collectors. Both groups maintain they are acting in the best interest of the species of concern: for conservationists, this typically means working to construct protected areas or habitat management plans, improve conservation enforcement, and restrict species trade; for many collectors, it means ensuring that people who desired them as ornamental plants around the world could acquire them sustainably. If being a conservationist means working to ensure the enduring survival and persistence other wild species, the collectors assuredly see themselves in this light—even when breaking international trade regulations in the name of conservation.

Beyond these contests over the legitimacy and moral authority, my field notes also reveal how both plant collectors and conservationists feel their way through the weight of extinction as an unnerving proximity to permanent absence. This small moment in Brazil with *Melocactus azureus* revealed meanings behind feelings of frustration, worry, and enjoyment experienced in relation to species flourishing and diminution in a moment of uncertainty. The desire to rejoice in abundance described by Tom, set against the dismal gloom when confronting the march of a population under threat from housing development, elicited a variety of responses from the collectors I travelled with. And yet in these fantasies of abundance and extinction, the ecology of the plants felt profoundly absent. What sorts of relations did *Melocactus azureus* keep; what other kinds of life might be lost if it truly vanished? How might abundance be measured otherwise, as a kind of flourishing? Alternatively, in places where the species seemed to be thriving, what kinds of relations were sustaining it? Multispecies relations in times of extinction are fraught with uncertainty, but possibility as well. How might we learn from these ecologies to foster such growth elsewhere?

The Opposite of Extinction

Turning meadows into forests on Cape Ann, **Nicholas Anderson** knows nature wants more from us than potted plants and packaged seeds.

Nicholas Anderson is an ecological land manager, consultant, and arborist in Massachusetts, where he is a founding member of the Creative Commons Collective of Cape Ann.

Amid the old fields, town lands, and quarry landscapes of Cape Ann, Massachusetts, I make meadows with well over a hundred species of what I refer to as charismatic, native weeds. Aside from some annuals, few of these plants—perennials, ferns, rushes, sedges, certain, shrubs, bunch grasses and tree seedlings—are what people would ordinarily call weeds, but they are plants that spread and reproduce with great speed and aggressiveness, and they make up a portion of my bottomless grab bag of natural resources.

Every year, I dig out the ever-spreading surplus of my preexisting meadows and make them into many more. These extraction events are sometimes lovingly measured and specific. I recently counted over forty species of native perennials that I can grasp between my thumb and forefinger and yank from low on the stem, retaining just enough root material to make new populations without diminishing the old ones. But sometimes my meadow harvests are less specialized and more impulsive. A few weeks ago, in early March, I plunged my shovel into a largely dormant meadow to extract plants and dirt for a new project. I pulled out black soil, roots, and rhizomes replete with three years of accumulated seeds from intended species, but without any certainty of what plants were being spread. I think of such actions along the lines of scooping a net into a well-stocked pond, extracting innumerable species of fish, and delivering them to repopulate

Illustration by Matt Huynh

barren pools nearby.

Towards October, a season of self-satisfied gazing at insects and the last blooms of blue mist flower, asters, and goldenrods gives way to seed collection. Over the span of a couple of months, I fill jars and paper bags with all manner of seeds. Sometimes my gathering forays are haphazard and spontaneous, so I usually end up with a few unlabeled bags of fluffy seeds in the back of my car that I don't recognize or remember. Sometimes I walk in the woods without a container, and I fold the seeds of several species together into a handkerchief. All such seeds are added to a collection that might be likened to a "Slush Puppy" with every syrup flavor mixed in one cup.

I generally forget about the seeds until partway through January, when they start to weigh on my mind because they're taking up floor space. I then either pack them in damp sand and store them outside for cold stratification, or I find spots of soil to add them to. Most conventional, mowed landscapes contain innumerable bare spots in the winter whether from frost heaves, animals, foot traffic or other such disturbance events. These are my favorite places to throw down seeds. I reach into whatever bag or jar I'm carrying and sprinkle them in, followed by a gentle stomp of the foot. I like to linger in the hollowness of this moment. I have performed an action but there is no perceptible reaction. There is an absurdity to it, and I try to sit comfortably in that space. Often, I pass sequentially over the same patches of dirt with many different species that I suspect might germinate easily there. I don't make notes and largely try to forget about them so that I'm pleasantly surprised later in the year.

When I started in horticulture, I became a plant hoarder almost immediately. I wanted to experiment by growing everything I could get my hands on—especially the great variety of native plants discussed by gardeners the way that cinephiles discuss favorite directors. I constantly acquired little divisions from my family, friends, and cracks in the pavement as they spilled out from public horticulture projects. For a while, I was something of a true believer at the intersection of native plants, pollinators, and ecological restoration, and I thought there must be "solutions" for every piece of land in the proper groupings of species: Right plants, right places.

I discovered that roughly imitating the combinations of native species that one might find at the disturbed edge of a forest or country road is a fast, free way to create a piece of land that is beautiful and resilient, requiring virtually no maintenance whatsoever while providing for perpetual expansion. The secret lies in cultivating abundance, density, and diversity—that, and a form of attentive affection.

Working in this manner over the better part of a decade has changed my relationship with time, people, culture, travel, consumerism, and my very subjectivity. The aesthetic impact of plants hits us so much deeper than we typically acknowledge. Down in the tissue, the bones and traversing the blood brain barrier with ease and frequency, plants smuggle themselves into our consciousness. They naturalize, invade, infect, and entangle. I came to plants to heal my wounds—and maybe some of those in the land. Perhaps along the way, I could become a skilled ecological restoration practitioner. I found that both things were possible, but I discovered something far more destabilizing.

When you look at vegetative nature properly, it almost takes on a menacing tone, effectively whispering, "we will bury

WELL SAID

"Those who measure life by counting the boxes and the losses rarely have a metric for persistence."

Rosetta S. Elkin in "Narratives at the Margins of Extinction," page 66.

you." I think I first had this revelation walking off the trail in Harriman State Park, where I encountered an old estate that had been swallowed by trees. You could still see little remnants of exotic plants that were cultivated but they were just traces, disappearing into the green maw. Elsewhere in the same park I found an abandoned, asphalt parking lot that was being devoured by gorgeous vegetation.

I work where I grew up, on Cape Ann, Massachusetts, a place that supplied much of the granite for the foundations of Boston, New York, Philadelphia and beyond. Sitting at the edge of a quarry in light dappled by grey birch and shadblow, in a landscape that looks to have been divinely designed, I can imagine men 150 years ago breaking their bodies and filling their lungs with dust to make pits in the earth, which are often over 100 feet deep and many hundreds of feet across. Now, these places are exquisite oases. They have an integrity, beauty, diversity, and durability that is unrivalled by any botanic garden, and plants did it all by themselves, once the advent of concrete made the quarrying obsolete. When capital moves, nature comes back—not precisely the way that we want, but never without abundance and diversity.

American horticulture and the buying and selling of plants has always been and continues to be a significant source of climate and ecological breakdown regardless of the origin of species involved. Nursery production negates the abundance that wants to be ubiquitous around us and alienates us from the ways that plants really grow, reproduce, and entangle themselves with one another. We are told the best time to buy a tree is 25 years ago and the next best time is today—meanwhile, wonderful oak, black cherry, and juniper trees are heaving themselves through the pavement, just as avidly as Norway maples.

We have been told for so long that plants are delicate, expensive, and scarce—and we have made them thus in our landscapes. We have mowed, mulched, weeded, fertilized, deadheaded, and planted sterile cultivars for so long that we can't even see these practices for what they are: enactments of extinction. Most of us are so thoroughly estranged from nature that popular narratives about saving it through thoughtful consumerism are persuasive. But these only take us farther from where we want to be, where the earth needs us to be.

The secret lies in cultivating abundance, density, and diversity—that, and a form of attentive affection.

Instead, here's a vision from the meadows and quarries of Cape Ann: Bring people together in an underappreciated landscape that no longer needs to be mowed and give everyone a bucket of undifferentiated, charismatic, native weeds. Every planting combines community building with an immersive botanical education. Coming together, we find that vegetative nature is not scarce or delicate. Enjoying sunshine and camaraderie, we also can summon some curiosity and humility. People can start to care about these little spreading patches of grasses, ferns, and flowers that soon reveal tree seedling spontaneously emerging. Keep the trees that you like. Maybe yank out the Norway maples and buckthorn along with the tendrils of Asian bittersweet. If native plant purity is to be sought, the work will be greater, but allowing some knapweed, buttercups, and Queen Ann's lace might be a good way to start getting used to the way plants just insist on living together regardless of how we feel about it. Nature's best hope does not lie in gardening. It lies in recognizing and reconnecting with abundance. It lies in logging off and noticing that virtually anyone can plant like a bluejay. Anyone can plant like a fieldmouse or a chickadee or a duck. I want to plant like a beaver and use my powerful incisors to cut through the aluminum frames of greenhouses. Nature's best hope is not your perfected backyard. As the canopy begins to close and the familiar tree roots surface like muscular arms underfoot, flowers diminish in the meadows. But this is neither an end nor a beginning, but another turn in the cycle of succession. Working alongside the layering of leaves, seeds, and cambium rings, we can build forest frameworks in which beloved things can flourish. The opposite of extinction is not mere survival but entanglement, abundance, and emergence.

An Empty Pot

Seeking stories of extinction in museums worldwide, **Dolly Jørgensen** finds a curated absence at Royal Botanic Gardens Kew.

It is just an empty pot. The huge orange clay container stands amidst verdant vines, ferns, and lush temperate bushes, but nothing was visibly growing in it. A small black sign in the barren soil labelled it *Nesiota elliptica*.

A Saint Helena olive (*Nesiota elliptica*) used to grow in this clay pot with sprig decoration marking it as property of Royal Botanic Gardens Kew. At the end of 2003, after battling a fungal infection, the tree died. While the death of a tree is nothing special for botanical gardens like Kew, the death of this tree was different. This was the endling Saint Helena olive, the last of its kind.

The Saint Helena olive, which was in the buckthorn family and unrelated to true olives, was endemic to the South Atlantic island of Saint Helena. It grew in the upland cloud forests as a small spreading tree with deep grey foliage and small pinkish blossoms in the summer. But then came the colonizers.

Dolly Jørgensen directs the Greenhouse Center for Environmental Humanities at University of Stavanger, Norway and is coeditor of *Environmental Humanities*.

Saint Helena was discovered by Portuguese explorers in the early sixteenth century and the East India Company of Britain established the first permanent settlements on the island in the mid-seventeenth. The island became a regular stopover port for ships needing to replenish supplies on their return voyage from Asia. Slaves labored on the plantations, particularly growing coffee, the seeds of which were first imported in 1733. Forest was cleared by humans, as well as by feral goats, which devoured young tree shoots.

The destruction took its toll on the tree. When Joseph D. Hooker described *Nesiota elliptica* in the 11th volume of his *Icones Plantarum* in 1871, it was already quite rare. "A very few trees now remain, probably not more than twelve or fifteen at the most," remarked Royal engineer John Charles Melliss in *St. Helena: A Physical, Historical and Topographical Description of the Island, Including the Geology, Fauna, Flora and Meteorology* (1875). He had collected the herbarium specimen (K00214561) for Kew, and his wife, Alice Elizabeth Louisa Melliss, executed its botanical illustration for his book. At that time, the last few trees were barely clinging to life on the northern side of the highest mountain, Diana's Peak.

These soon disappeared. A wild specimen was eventually discovered in 1977, and before it died in 1994, a successful cutting was propagated from it. That single cutting had lived at Kew in the pot that now stands empty. All that remains of *Nesiota elliptica* is some genetic material stored in the DNA and Tissue Bank at Kew and the soil that once enveloped its roots.

Globally, extinction is happening rapidly—so rapidly that many scientists are saying that we are in a Sixth Mass Extinction event. This biodiversity loss is most acute on islands like Saint Helena, where species evolved for specific niches which have been disrupted by European colonizers and their imports. The Saint Helena olive is not as special as we might think at first.

If you travel the halls of natural history museums, you will commonly encounter the remains of extinction. It is relatively

Illustration by Matt Huynh

easy to come face-to-face with the passenger pigeon, which in the early 1800s numbered in the billions before a precipitous decline due to market hunting down to zero in 1914, and the thylacine, which was hunted as an agricultural pest by White colonizers on Tasmania and became extinct in 1936. There many other extinction remains on display too, from great auk eggs that look like a Jackson Pollock painting to awkward dodo skeletons to roaring Cape Lions.

But very few natural history museums put extinct, or even endangered, plants on display. Muséum national d'Histoire naturelle in Paris is one of the few who does. In their Hall of Threatened and Extinct Animals, which is the largest dedicated display of extinct and endangered species in the world, a wall of herbarium sheets gives a glimpse into vegetation loss with two specimens labelled as extinct: Violette de Cry (*Viola cryana*), a violet endemic to limestone outcrops of the Cry region in north-central France, disappeared by 1930, and Fleur de St Louis (*Hibiscus liliiflorus*), a small hibiscus tree of the Mascarene Islands, which is extinct on Reunion Island (although it is still present as two wild individuals on Rodrigues Island). In all of my research visits to more than 70 natural history museums across the globe, *Viola cryana* is the only globally extinct plant specimen I encountered on display. The herbarium specimen of the violet—with its four individual plants pasted flat with brown dried stems, tangled thin roots, and pressed flowers faded to a dark ivory color—gives very little indication of how this plant would have appeared in nature. Unlike the animal taxidermy specimens in the room, which are preserved in three dimensional forms and with some semblance of original colors, these sheets capture little of the vibrancy of life.

Very few natural history museums put extinct, or even endangered, plants on display.

Perhaps, then, displaying an empty pot in the Kew greenhouse was the most appropriate choice to mark the extinction of the Saint Helena olive. Rather than encountering some brittle leaves on display, an empty pot reminds the visitor that extinction leaves an absence, a hole that will remain unfilled. This is the Saint Helena olive.

PRECISION HORTICULTURE

Micropropagation

The Southeastern Center for Conservation (SCC) at Atlanta Botanic Garden recently used micropropagation to reproduce endangered woody plants. Called propagules, these plants are grown under sterile lab conditions (in vitro) from miniscule pieces of plant tissue. This technique is useful for preserving woody plants whose seeds may be difficult to collect or store. In vitro propagules are kept in vials at low temperatures to slow growth rates. The SCC established cultures of three endangered magnolia and oak species (including *Quercus boyntonii,* mentioned on page 9).

DANNY STEVEN S., CC BY-SA 3.0

Buckleya distichophylla

By Michael S. Dosmann

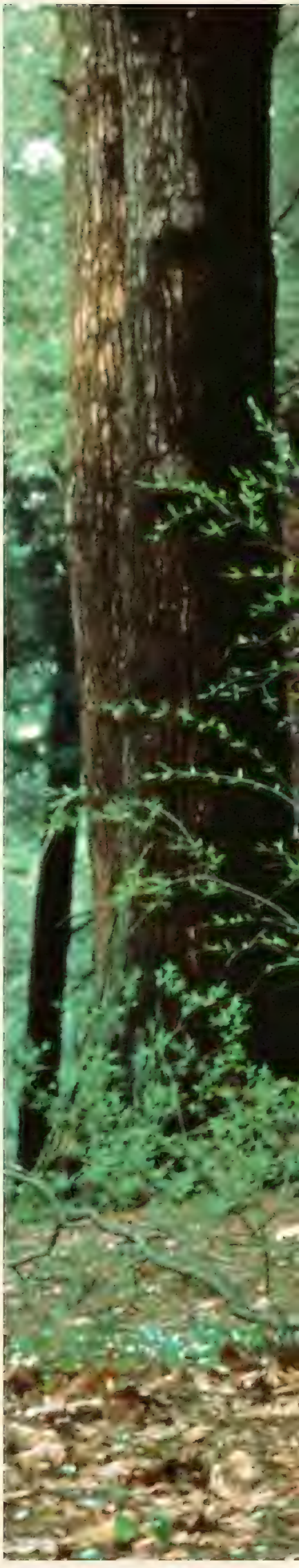
I often get questions about superlatives: which accession is tallest, widest, oldest? The last I can answer in several ways: A bonsai, *Chamaecyparis obtusa* 'Chabo-Hiba' (877-37*A), which began its training in 1737, is our absolute oldest. One *Quercus alba* (346-2010*A) on Peters Hill is about 220 years old, germinated in place long before the parcel's acquisition. The oldest in-ground accession, brought from elsewhere, is 245-46*A, *Buckleya distichophylla*.

Native to the Blue Ridge Mountains of Tennessee, North Carolina, and Virginia, the piratebush is at moderate risk of extinction because its few populations are under threat from habitat loss and the decline of host species. Host species? Yes, this member of the Santalaceae is a hemiparasite. Although fully capable of photosynthesis, its roots parasitize other species to better acquire nutrients and sugars.

Our shrub has grown among the hemlocks on their eponymous hill since accessioning in 1946. Its Harvard history goes deeper, however. Asa Gray acquired it in 1843 during an excursion to Southern Appalachia. The plant grew in the Harvard Botanic Garden until the garden's extinction. That the plant—a centenarian *then*—survived transplant to its new environment is a testament to its tenacity, and to the determination of the collections staff.

In nature, one of piratebush's hosts, *Tsuga,* is under threat from Hemlock Wooly Adelgid, an introduced insect pest. For over 25 years, the canopy of Hemlock Hill has been under the same threat. We've stabilized the hemlocks, but the environment has shifted since Ethan Johnson took the photo decades ago. As crowns thinned and neighboring trees died, the conditions around the *Buckleya* worsened. Shade cloth and supplemental watering have ameliorated some challenges, and this spring we transplanted a young *Tsuga canadensis* into its root zone to re-establish ties to the community.

There are different forms of extinction: loss of an entire biological lineage—a species—as well as the extinction of an individual, independent lineage like this plant. Should it die without issue, we would lose something special—a plant touched by many who have come and gone. Collected by Gray, observed by Charles Sargent who curated the campus garden, vouchered by John Jack, written about by Richard Howard, visited by countless others. It is a throughline passing across Arboretum history. In either case, extinction cannot be an option.



Michael S. Dosmann is keeper of the living collections at the Arnold Arboretum.

Unassuming and enduring: *Buckleya distichophylla,* 245-46*A, on Hemlock Hill. *Photograph, 1989 by Ethan Johnson*

SPECIAL ISSUE

Collections, Extinction, Abundance

By Yota Batsaki and Peter Crane

This conversation among scientists, artists, humanists, and horticulturists began from the observation that plants are relatively neglected in the rhetoric of extinction. This is surprising, given that plants, through their photosynthetic alchemy, supply the conditions for almost all other forms of life on earth. None of us can opt out of our fundamental dependence on the energy they provide. Yet conservation is focused disproportionately on the charismatic megafauna that themselves are fundamentally reliant—directly or indirectly—on the plants of the ecosystems they inhabit. This obliviousness to plants persists even as historians and cultural critics have become interested in the social, ethical, and emotional aspects of extinction. A recent special issue of a premier journal of environmental history,

Precarity and resilience: with hemlock crowns thinning under pressure from wooly adelgid (*Adelges tsugae*), the woodland on Hemlock Hill made room for a flush of sweet birch (*Betula lenta*), as seen in this 2008 image. *Photograph by Richard Schulhof*

for instance, calls on historians and scientists to join forces in the study of extinction, yet the editorial does not refer to a single plant.[1] Likewise, two important extinction studies published in the last decade contain, among them, a single essay focused on a plant.[2]

One reason for this relative neglect may be the ubiquity of plants: they constitute approximately four-fifths of all living matter on earth.[3] But at a time of accelerated habitat destruction and climate change, the seemingly endless variety of plants is being eroded, resulting in local extirpation and sometimes complete elimination. Scientists and humanists are debating whether we are traversing a new geologic epoch, shaped by the actions of humans: the Anthropocene. But there is no doubt that the impact of human needs or wants is shaping the fortunes of plants. As botanist John Kress and ecologist Gary Krupnick have argued, species useful to humans or adaptable to human-caused disturbance, including domesticated crops and weeds, will emerge as winners. By contrast, species with specialized habitat requirements or narrow distributions, as well as overexploited useful or charismatic plants, or species that are simply obscure and overlooked, will be the losers of the Anthropocene. Adaptability to human ends too often will be the criterion for "surviving ... the coming biodiversity bottleneck."[4]

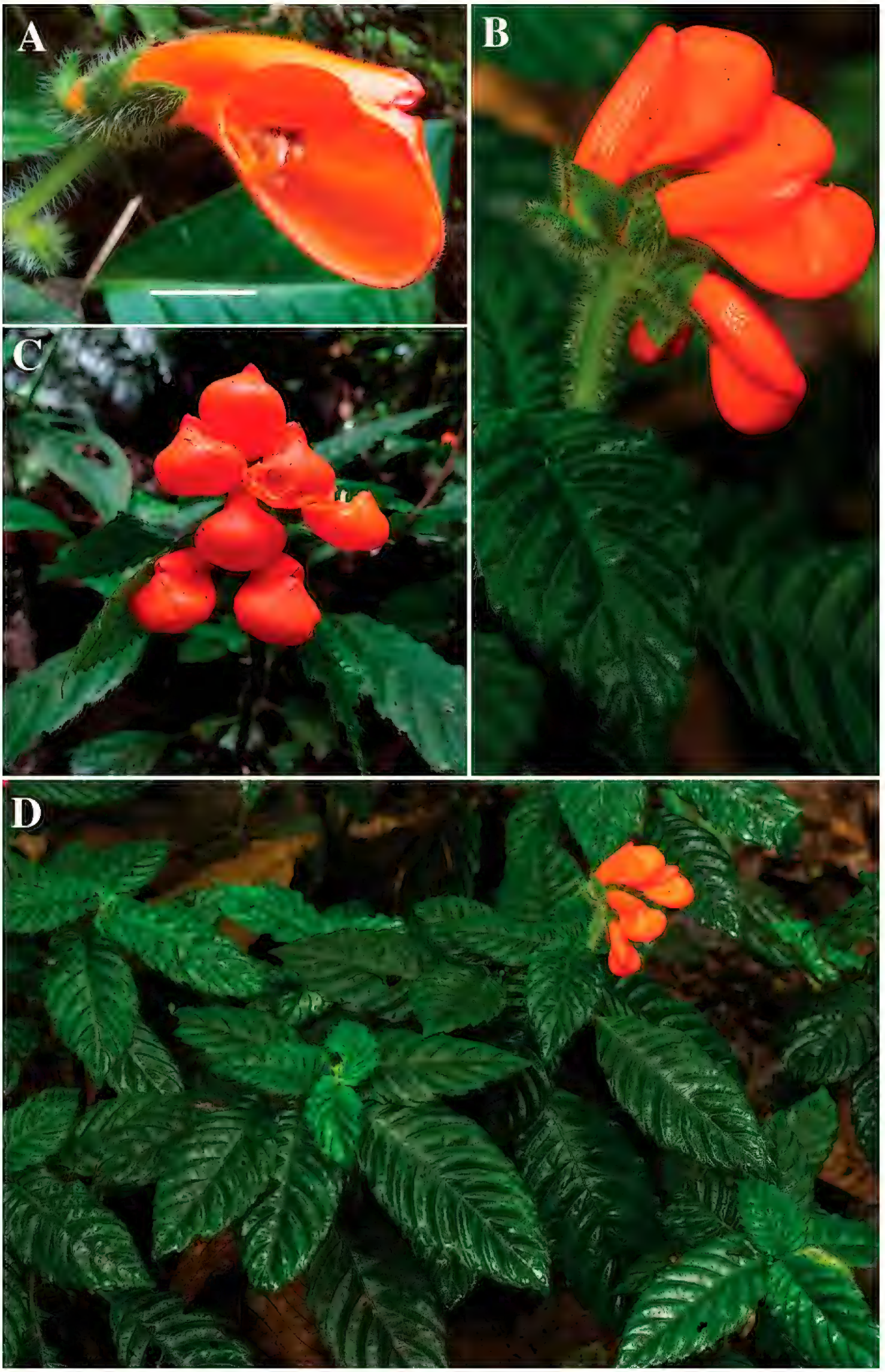
What happens when we reflect on extinction through the lens of plants, rather than animals? The recent efflorescence of cultural studies focused on plants is rooted in the theoretical framework of animal studies—and, more broadly, to current critical interest in non-human entities as historical agents. But the question of extinction also highlights how the categories applied to animals may not readily translate to plants. And these differences are most productively accounted for not only in terms of our zoocentrism or the inferior status of plants in many Western philosophical traditions, but in terms of plants' distinct evolutionary characteristics.

For example, the defining proposition of the Anthropocene is that humans have become geological agents: the evidence of our destructive impact on the Earth's biota will, the argument goes, be inscribed in the earth's strata. Yet, while evidence of extinct plants is abundant in the fossil record, large-scale plant extinctions coincident with the five mass extinction events of the past are harder to discern. Global plant life was undoubtedly perturbed during times of previous mass extinctions, perhaps with profound consequences, but evidence of wholesale synchronized extinction of major plant lineages is much less clear. The life cycles of plants are attuned to challenging times: their flexibility of growth often imparts resilience, and their seeds and spores can travel or lie dormant for a long time.[5]

Wrestling across disciplines with extinction in the world of plants reveals it to be a nuanced and contested category, even a historical one. It changes the questions we want to ask: for instance, should we focus on the end point, or invest our care and concern earlier in a plant's journey to disappearance? What should be the unit of care: the individual, the species, the habitat? An additional complication are species deaths that turn out to be exaggerated; witness the *Gasteranthus extinctus,* a Lazarus species in Ecuador that was assumed to have gone extinct due to habitat destruction but was found in tiny remnants of the cloud forest.[6] Yet, this miraculous reappearance simply means that *Gasteranthus* has moved from "Extinct" to "Critically Endangered." Some plants have even secured a reprieve through their relationship with people, such as *Ginkgo biloba,* whose unique place in plant evolution is matched by its long association with humans, who may have saved it from extinction.[7] The resilience of plants is extraordinary, but they are still vulnerable to habitat fragmentation, degradation, and destruction, just like animals.

So is the past—as far as we can discern in the geological record—an adequate guide to what lies ahead? Or does the unprecedented acceleration of processes that used to unfold over centuries or millennia interfere with plants' ability to evolve, migrate, and survive? Might plants be less resilient to a human-induced sixth mass extinction through the combined forces of habitat destruction, climate change, soil erosion, and the disentangling of mutualistic and other relationships with other organisms? It is undeniable that most species that have ever existed have gone extinct; eliminated most often by what scientists call the "background extinction rate" unfolding inexorably in the deep time of evolution. Yet our moment may be different.

Extinction today, understood as the accelerated end to long evolutionary processes, throws into relief the unsettling and clashing temporalities of our time: the slow violence of pollution and global warming alongside the great acceleration of carbon emissions and the erosion of biodiversity.[8] We are witnessing the unprecedented collision of deep time—the time of species evolution and the formation of complex mutualistic and other relationships—with the



Field images of *Gasteranthus extinctus* showing distinguishing features, including (A) corolla with inflorescence branches; (B) relatively short peduncles; (C) relatively fewer flowers; and (D) elliptic leaves. *Photographs by X. Cornejo, R. Fortier, N. Zapata. Scale bar: 1 cm. Part of: Pitman N. et al. (2022)* PhytoKeys *194: 33-46. CC BY-SA 4.0*

Dating to the Triassic, *Ginkgo* is an ancient lineage, which survives today in part due to a long history of human care and fascination, exemplified by this specimen (671-77*A) in the Larz Andersen Bonsai Collection. *Photograph by Kyle Port*

historical time of human-induced climate change and habitat destruction. Plants are fundamental to our sense of place, and their gradual disappearance not only disrupts the ecosystems on which we rely for survival, but also deeply ingrained forms of spiritual and communal belonging that we mourn. Indigenous communities have borne such losses for centuries; now they are becoming, albeit still unequally and unjustly distributed, a global phenomenon. Local extirpation may be even more painful than extinction; the latter a planetary category that we may hold at arm's length; the former an intimate assault on our habits and sense of belonging.

The loss of living species also evokes nostalgia for their preserved remnants, imbuing scientific collections with new layers of emotion and significance. Several essays in this issue refer to the herbarium as a practice and a space for thinking through extinction and its opposites: abundance, survival, re-emergence. The herbarium provides fertile ground for such inquiry because of its dual nature as a technology of preservation and (now) an archive of loss. The creation of early herbaria was fueled by an encyclopedic desire to document all plant life, an ambition only partially realized. Yet the urge to collect and preserve, coupled with new technologies of digitization to which the herbarium sheet lends itself extraordinarily well, have resulted in millions of specimens that are finding new uses in tracking biodiversity. At the same time, the varied scale of the herbarium, from the vast collections of the Smithsonian to the intimate collecting of Henry David Thoreau, can feed both grand and local narratives.

An especially fertile space for thinking through extinction is the botanic garden. A collection of plants with provenance, the botanic garden is the living equivalent of the museum (a locus of encounter and display) and the archive (an organized repository of information). As an institution, the botanic garden has undergone many transformations in its roughly 500-year history: from the physic gardens that accompanied schools of medicine in the early modern period, to the role of botanic gardens as laboratories of imperial botany in the age of empire, to active hubs for contemporary plant science and conservation. The botanic garden is therefore a unique site (humanists would say, a heterotopia or "other place") where different kinds of knowledge come together; not

only science and horticulture, but also the historical and cultural information enshrined in their adjacent collections of economic botany and libraries of botanical publications, fieldnotes, and illustrations.[9] The increasing attention to botanic gardens among scholars in the humanities attests to this cultural and historical interest, which also explains one fundamental difference between, say, the botanic garden and the zoological park. Not only are plants a major contributor to our sense of place, but the garden has been a privileged arena in so many cultural traditions where the relationship between nature and culture, humans, and our environment, is constantly negotiated. The botanic garden is, therefore, a site of heightened attention to human-induced extinction and its possible remedies.

For plants on the brink, or even extinct in the wild, the botanic garden is also a place of refuge, a space where continued existence can be secured. Many botanic gardens are also now developing seed banks, leveraging for conservation purposes the inherent ability of many plants to survive environmental hardships as dormant seeds. As is sometimes said, there is no technical reason why any plant species should go extinct, and botanic gardens and seed banks operationalize that idea. But the larger question is whether plants in the safe havens of botanic gardens and seed banks are but the living dead—a fraying evolutionary thread no longer supported by the ecological tapestry of which they were once part.

A further question concerns the moral and ethical bases of establishing priorities for the intensive species care that is ex situ conservation. Different stakeholders are interested in myriad plants for diverse reasons, and in some circumstances the urge to collect, and perhaps protect, may itself be an act of ecological vandalism. Collecting is increasingly regulated at local, national, and international levels, with many benefits but also unintended consequences. The law is a blunt instrument. It used to be said "if you have a rare plant give it away," but this simple advice, focused on reducing the risk of ex situ extinction, is increasingly thwarted by multiple legal layers that seek to pursue other valid aims, such as enhancing "biosecurity" by reducing the spread of pests and disease, or eliminating the incentives for collecting plants that are valuable, rare, or endangered in the wild.

Extinction is extreme loss, and as such it captures the imagination and provokes strong emotions. Our attempts to understand, and perhaps avert it, must contend with both knowledge and ignorance, presence and absence—and so they may call for, alongside other epistemic encounters, the sensitive and elliptical resources of poetry as a way of knowing and feeling. But perhaps the finality of extinction perversely draws attention away from the more gradual depletion of diversity and the continuing impoverishment of our relations to the natural world. Extinction locks us into a logic of scarcity—as shown in our fixation on the last remaining individuals or our nostalgia for lost species—when instead we might focus on how to nurture emergence and abundance.

ENDNOTES

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2 Caren Landman and Ashley Cunsolo, *Mourning Nature: Hope at the Heart of Ecological Loss and Grief* (McGill-Queen's University Press, 2017). Deborah Bird Rose et al, *Extinction Studies: Stories of Time, Death, and Generations* (Columbia University Press, 2017).

3 Yinon M. Bar-On et al., "The Biomass Distribution on Earth." *Proceedings of the National Academy of Sciences* 115: 25 (2018):6506–11.

4 Kress, J. and Krupnick, G. 2022. "Lords of the Biosphere: Plant Winners and Losers in the Anthropocene." *Plants, People, Planet* 4(4): 350–66, 351.

5 Traverse, A. 1988. "Plant Evolution Dances to a Different Beat." *Historical Biology,* 1(4): 277–301.

6 Pitman, N. et al. 2022. "Rediscovery of *Gasteranthus extinctus* L.E.Skog & L.P.Kvist (Gesneriaceae) at Multiple Sites in Western Ecuador." *PhytoKeys* 194: 33–46. https://doi.org/10.3897/phytokeys.194.79638.

7 Crane, P. 2019. "An Evolutionary and Cultural Biography of *Ginkgo*." *Plants, People, Planet* 1 (1): 32–37. https://doi.org/10.1002/ppp3.7.

8 The term "slow violence" is Rob Nixon's; see his *Slow Violence and the Environmentalism of the Poor* (Cambridge, Mass.: Harvard University Press, 2011). On the acceleration of human-driven change to the planet's life systems see John McNeill and Peter Engelke, *The Great Acceleration: An Environmental History of the Anthropocene Since 1945* (Cambridge, Mass.: Harvard University Press, 2016).

9 Foucault, M. 1986. "Of Other Spaces." *Diacritics* 16(1): 22–27.

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I THINK ABOUT TO READ

Hope in the Herbarium: A Record of What is Lost and Found

By Molly Hardy and Mason Heberling

The specter of extinction has breathed new life into the herbarium, lending a fresh relevance to the age-old practice of collecting dried and pressed plants. An estimated 400 million specimens found in over 3,500 active collections worldwide document the world's botanical diversity across space and time (Thiers, 2024). The organization of these samples into plant collections known as herbaria dates back to at least the sixteenth century. Later systematized and organized into cabinets, this centuries-long practice of plant collecting is steeped in science and culture, as once-living organisms, turned into scientific and historical objects, now serve as evidence of species that have gone extinct.

Fears and questions around plant extinction bring these uses into relief. An estimated 51 species have gone extinct in the continental U.S. and Canada since European settlement (Knapp et al., 2021). Worldwide, it is estimated that nearly 600 plant species have gone extinct in recent centuries (Humphreys et al., 2019). However, identifying plant extinction is challenging and the exact number is disputed (Knapp et al., 2020). As Gary Krupnick explains elsewhere in this issue, extinction comes in many forms and is not as straightforward as you might think (see "Gradations of Extinction," page 38). Evidence for absence can rarely be complete, leaving us with lingering possibilities that a species might still be waiting for re-discovery in the wild. Any comprehensive tally of extinction since European colonization of North America is further complicated by the reality that many species likely went extinct before being documented by Western science, a phenomenon which has been called "dark extinction." In the face of these challenges, it becomes especially clear that the physical record of herbarium specimens is necessary to our understanding and prevention of plant extinction (Corlett, 2023).

Just as the herbarium developed into a widespread practice in the early modern period (Flannery, 2023), the herbarium today is having a renaissance of its own—in the scientific sense, as it registers plant extinction and climate change, and in the cultural sense, as its role as a repository of cultural heritage continues to emerge. As seen in this issue, artists manipulate it to create and recreate commentaries on permanence, loss, and human/natural interaction (see "In Search of Thoreau's Flowers," page 54), and humanists ask questions about its

Opposite: Authors Mason Heberling and Molly Hardy examining plant specimens in the Smith College Herbarium in Northampton, Massachusetts. *Photograph by Nicholas Anderson*

historical trajectories, its logics, and its stories, both present and erased.

And yet, amid renewed interest in the herbarium, the collections themselves seem to be under threat. The most recent, and perhaps most public, of plans to deaccession an herbarium comes from Duke University, which houses the second largest private university herbarium in the U.S. Due to its size (roughly 825,000 specimens), the Duke Herbarium will likely be given away in parts, scattered across many institutions. "This will not only disrupt the storied historical context of the collection, it undoubtedly will lead to confusion about where particular Duke Herbarium specimens have gone," writes the American Institute of Biological Sciences in a recent letter to the University (2024). And Duke is just the most recent in a surge of such losses: dozens of herbaria have closed in the last twenty years, most without garnering wide public attention. At the same time herbaria are closing, there is some hope. More than 600 herbaria have been newly registered since 2016, yet 92 herbaria have closed and nearly 800 additional herbaria have been unresponsive to inquiries, suggesting inactivity or possible closure (Thiers 2024). Relatedly, the Royal Botanic Gardens, Kew, one of the premier collections in the world given the institution's long history of supporting botanizing expeditions around the globe, announced that the Kew herbarium will be moving to Reading, where we are told it will remain accessible to researchers, though distant from the institution's primary access point. A petition, which has almost 20,000 signatures at the time of writing, notes that "by isolating the herbarium at the new site over an hour distant, dividing it from the living collections in the gardens, from the library, from the Jodrell laboratories, [from] the MSc and PhD students and other scientists," Kew is effectively "removing" its own "beating heart" ("Keep Kew at Kew" 2024). With iconic images of tall ceilings and spiral staircases leading to historic cabinets, the concern for Kew's relocation highlights the importance of the herbarium, not as merely as storage, but as a convening space for inspiration, conversation, and innovation.

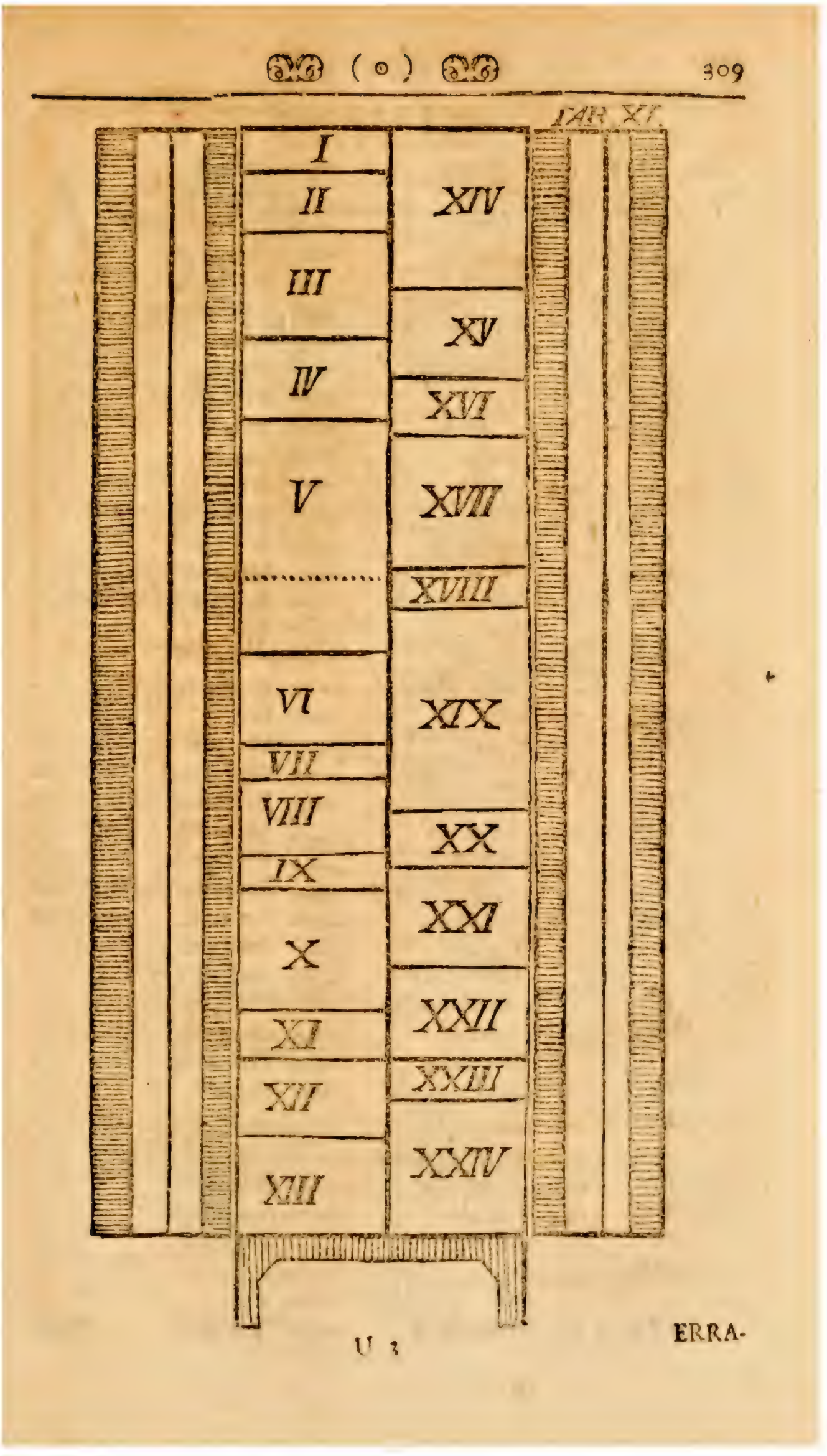
Scientists who protest the loss and relocation of these two premiere collections have noted the perverse irony: just as herbaria are being recognized for their value in understanding, and in some cases even mitigating, plant extinction, their own existence is threatened. Each specimen has scientific and cultural stories to tell, not only about what once was, but the future of plant life. This separation, this disruption, this scattering, this confusion, invites a return to the history of collecting in the United States. How did this hybrid natural-cultural collecting practice become institutionalized in the first place? And what changes in academic science, horticulture, and the institutions that keep collections are fraying these ties in our time?

The Herbarium as Cultural Heritage Object

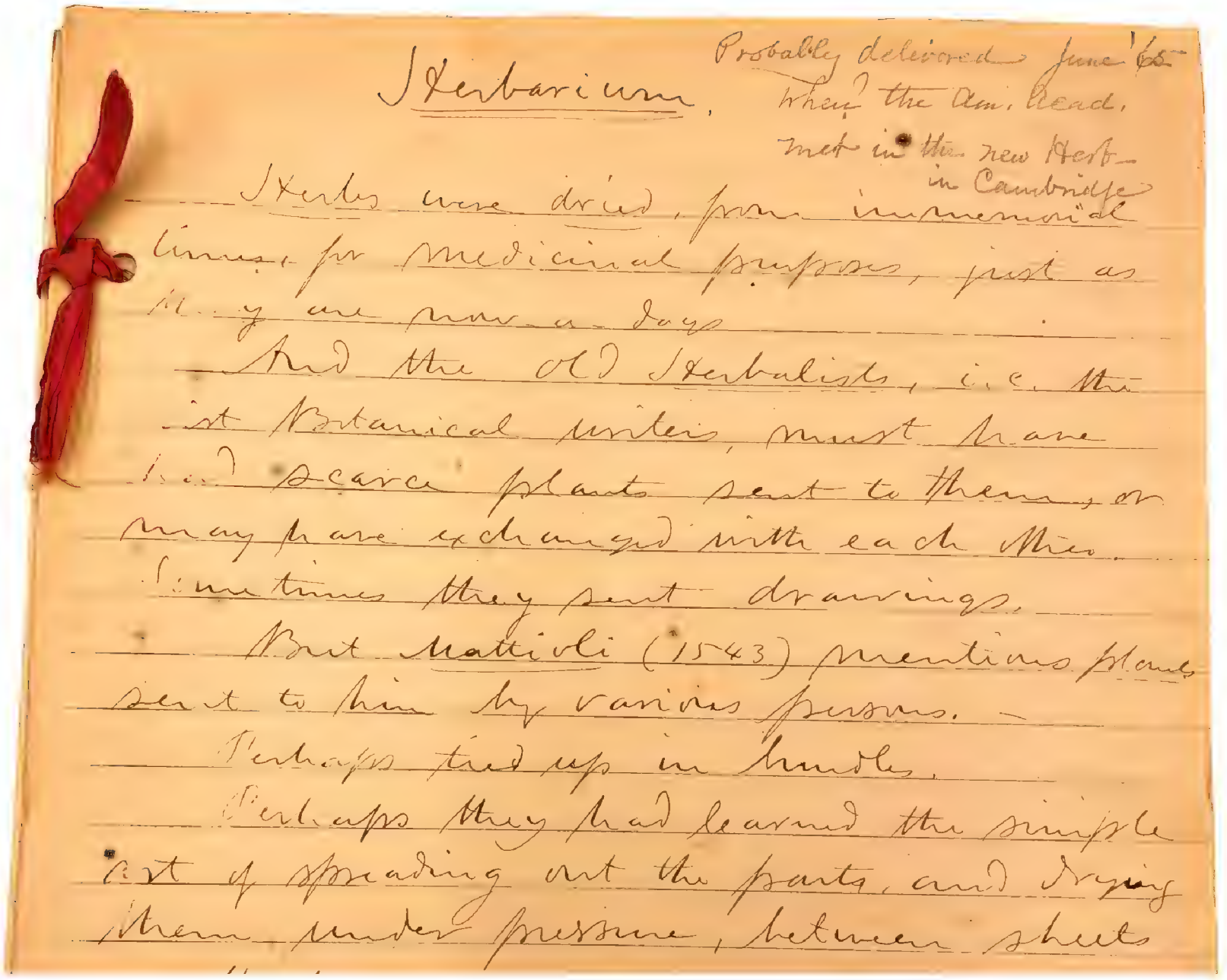
A figure known for any number of botanical "firsts," it was none other than Carl Linnaeus who initially specified the form the botanical information system should take, in remarkably practical and detailed plans, in his *Philosophia Botanica* (1751). He codified the storage of the pressed plants that botanizers had been collecting for centuries into a cabinet that reflected the intellectual control he was also proposing for the plant kingdom. Linnaeus offered explicit instructions for botanists collecting plants, detailing both immediate care for the specimen itself, as well as preservation techniques in cabinets. With each unbound leaf representing one specimen, the information becomes accessible on shelves, where each leaf can be placed and replaced, moved and shifted, adjusted as new knowledge presents itself to the herbarium being assembled.

In the form of an illustrative plate with measurements for each class, *Philosophia Botanica* precisely detailed the physical manifestation of this purpose-built cabinet for information storage and retrieval, as well as expansion (see plate, opposite). This structure anticipated the abundance that would come with collecting; when it was adopted in the United States, abundance was very much on the minds of its users as they strove to catalog the vast flora they encountered during westward expansion.

Like so much of what was true in the early Republic, the more the newly formed nation tried to differentiate itself from its European counterparts in its efforts to name and classify the natural world, the more it ultimately adopted their practices (Lewis 2011). The inheritance of the information system to govern the growing abundance of botanical knowledge in the form of mounted specimens was no exception. In the early nineteenth century, herbarium collections were hardly prized, however, and their early histories are ones of loss and languish, rather than of preservation and access. "The early institutional herbaria were poor financially, often did not have regular or appointed curators, and



Herbarium illustration from Carl Linnaeus, *Philosophia Botanica* (1751).
Accessed through the Biodiversity Heritage Library. Copy from the North Carolina State University Library


Herbarium.

Probably delivered June '65 when the Am. Acad. met in the new Herb. in Cambridge

Herbs were dried, from immemorial times, for medicinal purposes, just as they are now a days.

And the old Herbalists, i.e. the 1st Botanical writers, must have had scarce plants sent to them, or may have exchanged with each other. Sometimes they sent drawings.

But Mattioli (1543) mentions plants sent to him by various persons. Perhaps tied up in bundles.

Perhaps they had learned the simple art of spreading out the parts, and drying them under pressure, between sheets

Asa Gray's "Herbarium Talk," MC 42 (1865). Asa Gray papers, 1830–1953. Archives of the Gray Herbarium, Harvard University. *Photograph by Molly Hardy*

functioned largely as a storage place for the collections," writes Ronald Stuckey (1971). None other than President Thomas Jefferson deposited the journals of Lewis and Clarke at the American Philosophical Society upon their return in 1806, while "[a]ccident and loss" characterized the fate of their natural history collections (McCourt and Spamer 2004). As the century wore on, however, collecting became more ambitious and preservation followed suit, so that by the 1840s, the US Patent Office displayed bounty from the Wilkes expedition, before Congress transferred it to the newly formed Smithsonian a decade later.

At least at first, botanists in the early republic were less concerned about the archival work of nation-building than they were to name, know, and claim the flora of and for the new nation. Starting in the southeast with Mark Catesby's collecting on behalf of the Royal Society, and then in the northeast with John Bartram who sent plants to Europe and assisted Linnaeus's collector, Peter Kalm, American botanists started to establish their own collections. Increasingly, these collections became institutionalized, as David Hosack and John Torrey's collections formed the cornerstones of Columbia University and then New York Botanical Garden's herbaria (Johnson 2018). By 1865, Asa Gray's collection would become the cornerstone of Harvard's botanical collections, a move made with much calculation on Gray's account. Like Linnaeus, he understood the herbarium as a mode of preservation, as much as of organization.

When he first came to Cambridge in 1842, Gray had a "a small but significant" herbarium that resulted from his collaboration with Torrey on the North American flora, which "brought him collections, both living and dried, from far and wide" (Wood 2010). Twenty-three years later, when he bequeathed that collection (then numbering some 200,000 specimens) to Harvard, he reflected on what his collection, and plant specimen collections more generally, meant. In a lecture at the American Academy of Arts and Sciences, Gray expounded on the herbarium's role; it is, he said, "the only certain

Main Room, Gray Herbarium. Robinson, Benjamin L. Gray Herbarium photograph, 1900. ID 1177.1. Botany Libraries photograph collection, circa 1770–2020. gra00083. *Archives of the Gray Herbarium, Harvard University.*

record of species, the only means of transmitting to posterity the knowledge—we have acquired the only means of making the full comparison which Botanists have to make between the plants of different parts of the world." Gray saw Harvard as the site of secure transmission across time. Preservation could not come with the individual. Only the institution could secure that.

And Gray made clear that he had certain expectations for Harvard. He insisted that Harvard provide a fire-safe building to house the collection, which it was able to do thanks to a generous benefactor, as the President acknowledged in his annual report (Hill 1865). From the *American Journal of Science and Arts,* March 1865, we find a description of the Herbarium: with "the walls all hollow and ventilated, for greater security from dampness." The space is maximized for storage; "(t)he principal room, for the herbarium, is about 30 1/2 by 35 feet, and 19 feet high to the vaulted ceiling.... The space between the floor and the gallery is completely filled by the herbarium-cabinets ..." The one exception to this is the wall with the furnace made of soapstone, which "supplies warm air by registers." Chestnut wood forms the cabinets, casings, and woodwork, whereas hard pine "bedded in mortar" constitutes the floors. The building, we are told, has been constructed in "a thorough and durable manner," to "form a safe and permanent place of deposit for the collections" (Silliman 1865). The message here is clear: this place is one of permanence, one that will protect against the ravages of time.

And so, by the end of the nineteenth century, august institutions held both the records of natural and human history. Brick and mortar institutions are supposed to fortify these collections against the ravages of time, and the crumbling of such commitments makes the precarious status of today's herbaria so unsettling, and the need to communicate their importance so urgent.

In news coverage of the proposed closure at Duke and the division of collections at Kew, the focus has been on the scientific value of these collections. But

they also have a role to play as documents in the lives of the institutions that house them. Their records of collecting, their status as institutional histories, and their embeddedness in the moments in which they were and will be created, render herbaria relevant to more than a single discipline's purview. With growing attention to botany and horticulture in the humanities, we see disciplinary barriers breaking down; herbaria are key sites for new forms of scholarship and storytelling to emerge that critique imperial domination, highlight previously suppressed knowledge, and synthesize scientific and humanistic inquiry. The severance of collections inhibits such synthesis.

New Uses for Old Collections

Not long ago, herbaria were almost exclusively for taxonomists. That is not to say herbaria were not used by other scholars, including artists (Flannery 2023), but these were outlier cases, not the bread and butter of herbarium-based work. In recent decades, as new voices, perspectives, and disciplines enter herbaria, the uses of herbaria have also diversified (Heberling et al. 2019). Botanist Vicki Funk wrote "100 Uses for an Herbarium (Well at Least 72)," which, as the title suggests, enumerates the many ways herbarium specimens have been used across disciplines (Funk 2003); today, it is safe to say that these uses now easily exceed one hundred. While the taxonomic-centered uses remain, many unanticipated uses have emerged that were scarcely imagined by collectors and curators of generations past (Heberling & Isaac 2017).

Much of this increased attention and multidisciplinary use of specimens have emerged from access and awareness spurred by digitization. Herbarium specimens are receiving unprecedented attention due to recently developed methods, new perspectives, and perhaps most notably, their increased accessibility through widespread digitization. In the US, iDigBio, a program funded by the US National Science Foundation, is one such impactful initiative resulting in the digitization of millions of specimens at US institutions (Nelson and Ellis 2019). Global efforts, such as the Global Biodiversity Information Facility (GBIF.org), have created international networks that integrate a wide range of biological data from specimens to citizen science observations. These efforts have led to further interdisciplinary engagement with biological data (Heberling et al. 2021). The next generation of digitization and specimen use evokes the "extended specimen" (Lendemer et al., 2020), a concept that integrates disparate data sources, including physical specimens themselves, digital data derived from the specimen, historical information, and a whole constellation of data streams enabling transdisciplinary research.

Herbaria provide important holistic insights into the broader context of long-term biodiversity change.

With these shifting trends in herbarium use in mind, and in the midst of the current ecological crisis, herbaria have gone from documenting existence to chronicling loss. Herbaria (and natural history museums more broadly) have transitioned from the core mission of documenting biodiversity to documenting biodiversity change. And much of this change takes the form of loss of a scale and kind it would have been difficult for early-modern collectors to contemplate outside of apocalyptic visions. The herbarium of the past was refined to tell of what species exist in the world. The herbarium of today tells us what is no longer there; an archive itself, it has come to document how the land has changed.

Herbaria document biodiversity loss across scales: from individual populations at a given site to

the community of interspecies coexistence to global distributions. Though conservation efforts and public conversation understandably draw most attention to the endpoint of species extinction, herbaria provide important holistic insights into the broader context of long-term biodiversity change. These specimens allow for a broader understanding of ecological gains and losses, and importantly, they provide a more nuanced definition of extinction in modern times. Human-caused climate change, non-native species introductions, pollution, direct exploitation, and habitat loss are now recognized as major drivers of global biodiversity change, as summarized in the recent report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, 2019). While shifts in biodiversity may culminate in individual species extinction, complete species loss is relatively rare.

And though each herbarium sheet is a single specimen, isolated from the entangled existence it once had, these singular specimens have much to tell us about plant communities. Contrasted with species extinction, shifts in ecological interactions compose a different, more complicated kind of loss. Community-level shifts often appear slowly or subtly, occurring over large spatial or temporal scales, which make quantification difficult. Such changes often happen over decades or more, making the consequences difficult to perceive in one human lifetime. Therefore, without knowledge of past conditions, without the archive of the herbarium, it is easy to accept the present as the norm for all future comparisons, a phenomenon known as "shifting baseline syndrome" (Soga and Gaston, 2018). While some species may have never been recorded before extinction ("dark extinction"), other species may be slowly marching towards extinction before our eyes (see Krupnick, this issue). Certainly, local extinctions and extinctions of interactions are frequent. Ecology is dynamic, and even in the absence of modern anthropogenic disturbance, change is normal. But without a baseline for comparison, biodiversity changes go unrecognized.

Herbarium specimens have a critical role in overcoming shifting baselines. These specimens archive the past and document the present, so we can forecast our futures. Joseph Grinnell, a zoologist at University of California, Berkeley, is perhaps best known for developing and using the concept of the "niche" in the scientific field of ecology. But he was also an early advocate for the role of collections in biological conservation. In a forward-thinking treatise on the roles of museum-based research, he wrote: "At this point I wish to emphasize what I believe will ultimately prove to be the greatest value of our museum. *This value will not, however, be realized until the lapse of many years, possibly a century,* assuming that our material is safely preserved. And this is that the student of the future will have access to the original record of faunal conditions in California and the west, wherever we now work." (Grinnell, 1910; emphasis added). And here we are, at the very moment Grinnell forecasted, left to wonder if "our material is safely preserved" for much longer. And further, whether we are adequately documenting for the future.

Hidden Insights into Long-term Change

Perhaps more than ever, the time is now for herbaria to record and contextualize change in the Anthropocene. Yet the practice of plant collecting itself is on the decline (Prather et al., 2004), and many collections have far more specimens from a century ago than recent times. Research priorities have shifted away from natural history and basic taxonomy. Herbaria were once integral to botanical education with nearly every college, big or small, having a teaching collection, but now many universities no longer have a botany department or offer botany in the strict sense (Crisci et al 2020). Beyond the often-overlooked value of herbaria as physical spaces of education and inspiration for students, it is also worth noting that small herbaria have made big contributions to research, often documenting local diversity, which is not represented in larger, more internationally focused collections (Marsico et al. 2020). Though the recent announcement on the closure of Duke's herbarium is concerning, many smaller collections have languished in recent decades, and this neglect in turn has removed educational opportunities for students. Beyond concerns for the data and specimens themselves, herbarium closures ricochet further to affect the culture of collecting as a routine scientific practice. These declines in collecting, especially at local scales, severely curtail our ability to detect biodiversity change.

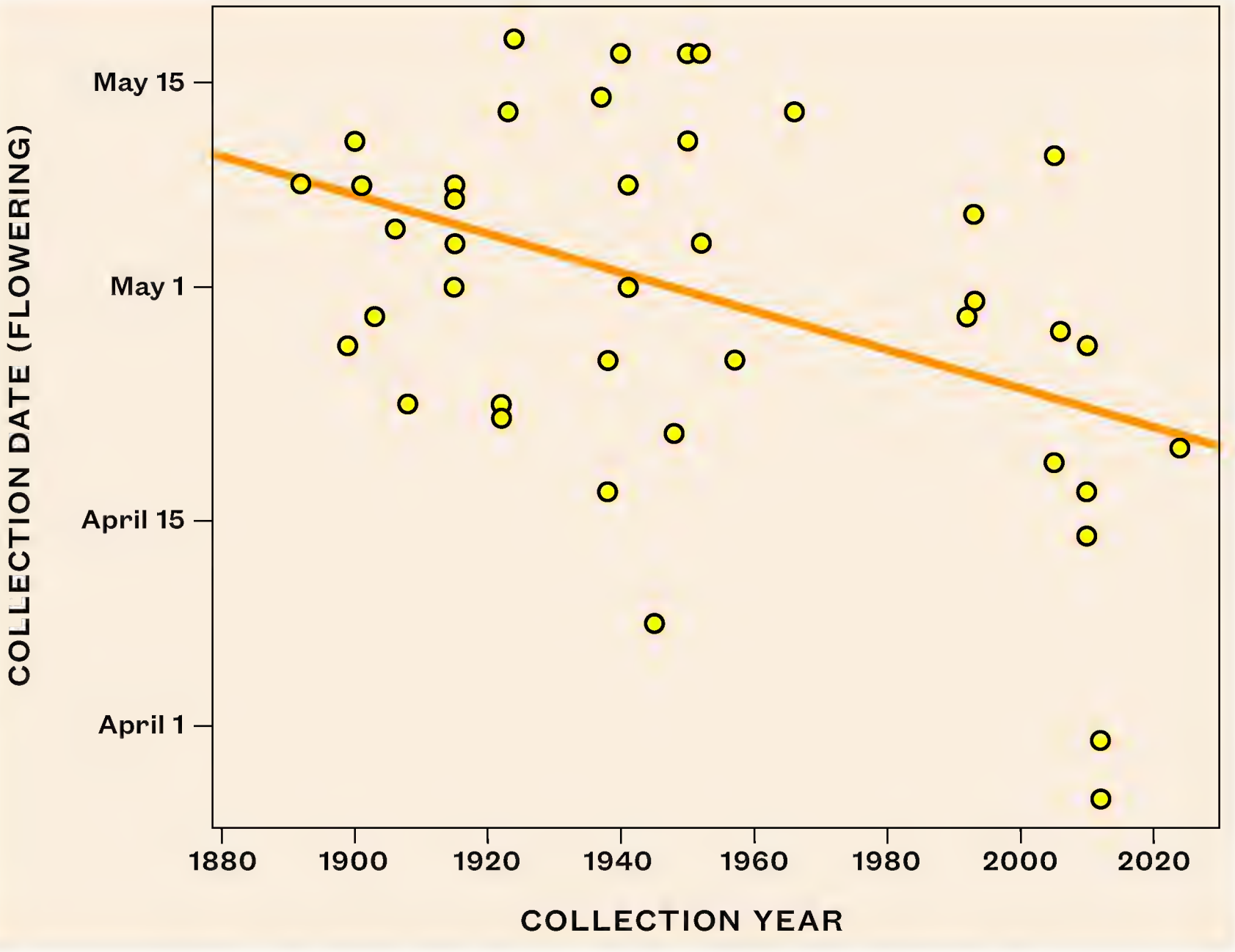
A recently initiated long-term project led by collection manager Bonnie Isaac at the Carnegie Museum herbarium in Pittsburgh, Pennsylvania, seeks to grow the collection in an active and intentional way. Botanists are revisiting specific sites across western Pennsylvania where past museum botanists sampled specimens many decades ago.

Two specimens collected in the same location near Pittsburgh, PA on the same date (May 4) but 102 years apart, the 1915 specimen (left) in full flower, the 2017 specimen (right) with leaves and developing fruits. *Photographs courtesy Carnegie Museum of Natural History*

About two dozen sites of varied habitats and geography are targeted across western Pennsylvania, with a collecting plan to comprehensively sample each site once per decade. A given site is sampled several times throughout a year in an effort to capture seasonal changes. As much as possible, sites are revisited on or near the same calendar date as historic collections to enable phenological comparisons, such as the timing of flowering. While research-specific and "non-targeted" general field collecting also continues, these re-collections give contemporary context to past collections, enabling focused comparison of biodiversity change, both now and in the future.

This specimen re-collection project was featured in the exhibition *We Are Nature: Living in the Anthropocene* on display at Carnegie Museum of Natural History from 2017-18 (Oliveira et al., 2020). Historical specimens collected in the region near the museum a century or more ago were paired with recent specimens. This juxtaposition not only elicited a sense of place and history from these specimens, but also tangibly, with decades of change perceptible in a single striking visual. The specimens themselves vividly illustrated the shifting of flowering times over multiple human generations. These locally collected specimens, juxtaposed side-by-side, evoke meaning and spur reflection in ways that are hard to produce from trendlines in data scatterplots alone.

Following the footsteps of past plant collectors can be eye-opening from both scientific and personal points of view. Some sites are now developed, and hence unable to be re-sampled. Some sites no longer harbor species that were collected a century, or even just decades, ago. Contrastingly, these same sites today regularly include new, introduced species that were absent entirely before but now thrive in abundance. The act of collecting makes you pay attention, often realizing more plant life is there than you might



In southwestern Pennsylvania, spring flowering dates for eastern redbud (*Cercis canadensis*) have advanced by an estimated 1.3 days per decade over the last century, as shown here with data from 47 herbarium specimens collected from 1892 to 2024. *Data from Carnegie Museum Herbarium*

think. Some new records of rare species are realized, often completely unexpectedly. If we look, there are many species (re)discoveries to be made, no matter where you are in the world.

Rethinking the Future of Herbaria

Albert Parr, director of Yale's Peabody Museum of Natural History, wrote in 1939, "The natural history museum of today is rather on the defensive. It can no longer claim justification by mere existence of its collections" (Parr, 1939). Nearly a century later, this need for the justification of herbaria continues. Herbaria cost money to maintain, take up physical space, and require human effort. Crisci et al. (2020) in a somewhat hyperbolic essay on what appears to be the "end of botany," points out the critical role of herbaria in curbing this doom. Curators will likely always need to justify their continued preservation and growth of collections, but the supporting evidence is clear.

In the modern era of biodiversity loss, the ethics of specimen collecting has come under question (Minteer et al. 2014). In addition to scrutinizing the need for more collecting, critics point to the financial costs of maintaining herbaria in light of alternatives such as non-lethal sampling of DNA and high-resolution photography. These and other recent technologies have not replaced the herbarium, however, but have augmented long-standing collection practices. For instance, the popular community science platform, iNaturalist.org, might at first seem to serve as a replacement for physical collecting. With your smartphone, you take a picture of an organism, and the observation is tagged with GPS coordinates and even identified with the help of artificial intelligence and a community of iNaturalist users. This method of biodiversity documentation clearly has power. But there are limitations to observations without physical specimens, which can be available for closer

inspection under a microscope, facilitate future measurements such as leaf size, or provide material for DNA analysis. On the other hand, details of the living plant, such as color or environmental context, can be lost in pressed specimens. Rather than view these approaches as conflictual, the complementary connection of iNaturalist with physical specimens enables new research (Heberling et al. 2018).

In addition to new technologies enabling new modes of botanical documentation, herbarium digitization has further changed the landscape of specimen use. Early in the digitization process, curators feared that administrators might see the scanned images as replacements for the physical specimens (Flannery 2012). Instead, digitized specimen images and derived data (label information, trait data, and more) have given the physical voucher new value. At the Carnegie Museum herbarium, requests for physical loans of specimens have actually increased, not decreased, upon digitization. Digitization enables access, and access enables new research, often across diverse disciplines of inquiry (Heberling et al. 2021).

Despite the heightened value placed on open data, the practice of collecting herbarium specimens has become less common. Every plant researcher should be collecting "voucher" specimens, or specimens specifically for the purpose of enabling verifiability of their research. Species names and our understanding of what a "species" is changes, but the specimens do not. These references are critical.

The history of natural history collections, including herbaria, presents problems that must be confronted. Historic collecting practices and the very institutions themselves are rooted in colonial mindsets of resource extraction and imperialism, often at the expense of indigenous communities. Highlighting the legacy of colonialism in plant collecting, most plant diversity is archived in herbaria in Europe and United States, despite most of this diversity residing in the tropics (Park et al. 2023). This geographical asymmetry calls for a more collaborative, global science. Whether some specimens should be repatriated is a discussion that needs to be had. In many ways, the digitization of specimens have enabled a more global botanical science, making specimens available to local researchers and enabling a more diverse botanical community (Drew et al 2017).

New methods and perspectives have revolutionized herbaria as physical spaces of discovery, innovation, and collaboration. In the digital age, millions of specimens from thousands of herbaria across the world are increasingly connected, alongside additional data and information, as a global "meta-herbarium" (Davis 2023). The burgeoning field of "Plant Humanities" has contextualized the interdisciplinarity of herbaria and the human connection. Improved methods of DNA extraction have made the herbarium an unanticipated DNA repository. Genetic analysis has even been done using fragment material from a single specimen of an extinct species (Zedane et al., 2016). Resurrecting extinct species from herbarium material may someday be a reality (Albani Rocchetti et al., 2022). Stopping plant extinctions is well within our reach, but doing so requires herbaria (Corlett, 2023).

Simply knowing there are millions of herbarium specimens preserved in herbaria across the world is not enough. They must be made accessible and used, placed in scientific and societal context. From across the arts, sciences, and humanities, together we are doing just that. Herbaria provide insight on plant diversity, biodiversity change, and society. These specimens are paradoxically both tombstones documenting what once was, but also objects of hope that provide insight into what can be. The future of herbaria, and indeed the future of plant conservation, is strong. But we must cultivate it.

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Gradations of Extinction

By Gary A. Krupnick

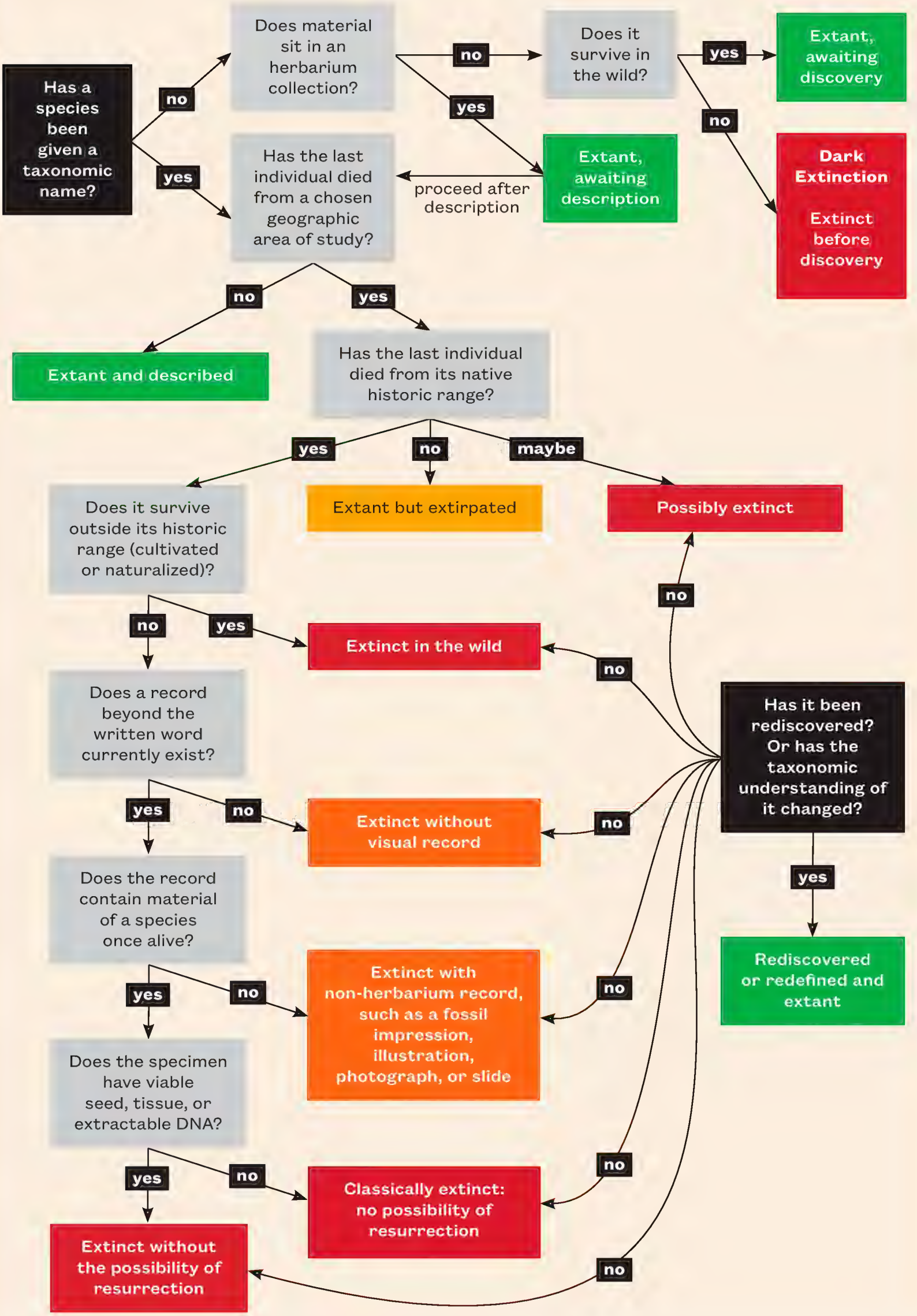
How does one define "extinct"? Is it clearly a black-and-white definition, or are there shades of gray? The Merriam-Webster Dictionary defines "extinct" as "no longer existing," while the IUCN Red List of Threatened Species defines "extinct" as "when there is no reasonable doubt that the last individual has died." Both definitions are clear and definite.

Extinction is not everywhere equal, however. A recent study documented plant extinctions over the past 250 years and included a published list of nearly 600 global plant extinctions (Humphreys, et al. 2019). Of the 571 extinct plant species listed in the study, 376 were defined as globally extinct (no longer extant in the wild or in cultivation) and 195 were defined as extinct in the wild (extinct in its natural habitat but known to survive in cultivation). That study was reviewed, tested, and scrutinized several times, and other studies have been published since with the additions of overlooked extinct species and the removal of species reported recently as extant (Knapp, et al. 2021; Rocchetti, et al. 2022). Curious to know how many of these species appear as specimens in the herbarium in which I work, the U.S. National Herbarium (herbarium code US), I matched the list of 571 extinct plants to our online database (US had recently completed a massive digitization project, and the data from its 4.5 million pressed specimens are now available online). I found that the US collection contains specimens of 98 extinct species, with another 48 species extinct in the wild.

The digitization process not only provides label transcriptions but specimen images as well. A close look at the images often reveals some descriptive words that the transcriptions might have missed (or transcriptions difficult to search).

Some specimen labels show that the collector of the specimen was aware of the species' rarity in the wild. For example, a 1927 specimen of *Argyroxiphium virescens* shows that collector Otto Degener was very aware of the rarity of this species in Hawaii. For the locality, he writes, "Koolau Gap, Haleakala Crater, East Maui, Fog-swept, moss-covered lava—very rare." Another Degener specimen, *Kokia cookie,* states, "On verge of extinction." (For an even more vivid example of a collector's awareness of a species' impending extinction, see "The Last Piece of Evidence," page 43.)

Tracing Extinction in the Herbarium



A specimen of *Weinmannia spiraeoides* (Cunoniaceae). No material on this sterile specimen can resurrect this species. *Courtesy of Smithsonian Institution*

Gradations of extinction multiply when considering the combined effects of species, collections, and culture. These gradations span a range, from extinct species that have never been discovered, to extinct species that theoretically may one day be resurrected by dried pressed material inadvertently found on herbarium sheets. Does the dictionary definition of "no longer existing" apply when one holds a specimen of an extinct species within one's hand? While the species may no longer be alive in the wild, the pressed dried plant still "exists." And what of herbarium sheets that have been destroyed during wars, fires, and floods? I present a flow chart (shown on page 39) that dives into the various gradations of extinction and examines how the representable records of long-ago species provides hope within an herbarium. My explanation of those gradations follows below.

SPECIES NOT KNOWN TO SCIENCE

Dark existence: Extant and undescribed

Estimates of the number of plant species currently present on earth range from 420,000 to 450,000 (Govaerts 2001; Joppa, et al. 2011), yet only ~378,000 accepted species have been described (WTO 2023). Extrapolations suggest that of the 70,000 species still to be described, approximately half await discovery in the wild, while the other half have been collected and are stored in herbaria, but due to the lack of taxonomic expertise or incomplete information have yet to be described (Bebber, et al., 2010). Some of these undescribed species rest as specimens that have been unprocessed in overburdened herbaria, and thus remain unavailable for study. For those specimens that have been processed, new species might be unnoticed, misplaced, or assigned to unidentified material.

Dark extinction: Extinct and undescribed

An immeasurable number of species have gone extinct before botanists gave them a taxonomic name. Boehm & Cronk (2021) use the term "dark extinction" for the extinction of undescribed species. The extinction rate of species today is far greater than in the past (De Vos, et al. 2015; Pimm, et al., 2014; Ceballos, et al. 2015; Cowie, et al. 2022). Thus, in a race against time, we continue to lose species from habitat destruction before species are ever discovered.

Case studies of dark extinctions: Knapp, et al. (2021) lament that "much of the eastern United States was affected by European settlement before botanical exploration began," and thus, "an untold number of plant species went extinct before discovery." Lambdon and Cronk (2020) estimate that for the island of St. Helena, there may have been around 10 unrecorded plant extinctions during the period 1502-1771. Similarly, using classical and Bayesian algorithms, Kristensen, et al. (2020) estimate that for Singapore between 304 and 412 plant species have gone extinct since 1822 before they could be discovered.

SPECIES NOT GLOBALLY EXTINCT

Extant and described

This category represents the 381,948 accepted plant species that are currently extant (WFO 2023).

Case studies of extant and described species: Some plant species are on the precipice of extinction, such as the 5,702 species assessed as Critically Endangered (IUCN Red List version 2023-1). Others are thriving in their native habitat, such as the 30,554 species assessed as Least Concern (IUCN Red List version 2023-1). While still others are thriving in introduced habitat as non-native and invasive species, such as the 474 worst invasive plant species that threaten native biodiversity and natural areas (Global Invasive Species Database 2023).

Extant but extirpated

Extirpation, also local extinction, refers to the termination of a species within a chosen geographic area of study. While the species is still extant elsewhere, scientists record when populations or subpopulations go extinct. For instance, species may be extirpated from a specific habitat (forest, bog, island) or an administrative division (country, state, providence, department).

Case study of extirpated species: A study conducted by Ebinger, et al. (2010) on 310 uncommon and rare native Illinois plant taxa found that 87 species are extirpated from the state, that most have not been seen in the state from more than 50 years, and some have not been seen since the mid-1800s.

Possibly extinct: Certain species have been assessed as most likely extinct, but these species require additional study and surveys for confirmation. IUCN states that "if, despite searches, the taxon has not been recorded since the collection of the type specimen, and there are threats in the area, a listing of Critically Endangered (Possibly Extinct) may be appropriate." The benefits to labeling a species as Possibly Extinct instead of Extinct is that protective measures and conservation funding will continue for a species

not believed to be Extinct. The IUCN Red List (version 2023-1) lists 569 species as Critically Endangered, Possibly Extinct CR(PE), an identification tag that can be attached to the CR category to highlight those taxa that are possibly extinct.

Case study of possibly extinct species: A study by Carrington, et al. (2017) highlights the species, *Xylosma serrata* (Salicaceae), a species assessed at Critically Endangered based on two collections in 1778 and 1980 from the same volcanic sites on Montserrat. The plant has not been recollected nor found during detailed surveys since the most recent eruptions of the Soufrière Hills volcano in 1995. Since a complete survey is necessary but difficult to execute due to the volcanic activity in the area, IUCN has listed this species as Critically Endangered, Possibly Extinct (Bárrios 2015).

Extinct in the wild: IUCN states that when a taxon is extinct in its natural habitat, but it is known to survive in cultivation, in captivity, or as a naturalized population well outside the past range, it is assessed as Extinct in the Wild. This category provided by IUCN also applies to plant taxa when viable seeds exist in storage facilities if there is potential for these seeds to develop into viable reproductive offspring. The IUCN Red List (version 2023-1) lists 45 species as Extinct in the Wild (EW). One species so listed is *Franklinia alatamaha,* which Rivers (2015) points out "has not been seen in the wild since 1803 despite numerous attempts to relocate it. It is successfully grown in many botanic gardens and arboreta around the world"—including the Arnold Arboretum, which has three living specimens (accessions 2428-3*A, 2428-3*B, and 254-81*C).

GLOBALLY EXTINCT SPECIES

Below are various categories of global extinctions that I crafted (not sanctioned by IUCN) that combine concepts of species, collections, and culture. IUCN's guidelines for Extinct is when "there is no reasonable doubt that the last individual has died." It is often quite difficult to confirm that a species has gone extinct, especially for species that are difficult to detect, such as cryptic, inconspicuous, silent, or identification is difficult, of which these examples apply to many plant species. IUCN defines a key aspect of the Extinct category to include "exhaustive surveys" that should be undertaken in all known or likely habitat throughout the species' historical range, at a variety of times (diurnal, seasonal, annual), and over the timeframe appropriate to the species' life cycle and life form. The IUCN Red List (version 2023-1) lists 129 plant species as Extinct (EX) while Albani Rocchetti, et al. (2022) identified approximately 360 extinct plant species.

Extinct without visual record: This category describes when all specimens of an extinct plant species have been destroyed, and there are no other visual representations of that species, such as a painting, illustration, or photograph, beyond the written word. During the course of history, many scientific collections have been partially or fully destroyed, either by natural events such as fires (e.g., Brazil in 2018; Escobar & Vogel 2018) and floods (e.g., Biltmore Herbarium in 1916; Alexander 2007) or by anthropogenic events such as war (e.g., Botanical Museum Berlin-Dahlem during World War II). Likewise, individual collections may have been accidentally or intentionally destroyed, such as when Australian biosecurity officers in 2017 incinerated a collection of plant specimens sent by the Museum of Natural History in Paris that dated back to the mid-1800s (Stokstad 2017).

Case studies of extinct species without visual representation: Rocchetti, et al. (2022) generated a list of 361 globally extinct species. For 30 of those extinct species, Rocchetti, et al., was unable to find any digitized specimens or specimens in the herbaria they contacted. Of those 30, it is unclear if photographs or illustrations remain. One species in the list, *Guettarda retusa* (Rubiaceae), is a Cuban shrub that has not been located since its time of description by Charles Wright in the nineteenth century. No type specimen was cited in the protologue (new-species description), and thus it's possible that no specimen exists for this species. Another species in the Rocchetti, et al., (2022) list is *Pavetta bangweensis* (Rubiaceae), a shrub from Cameroon. According to Manning (1996), the 1934 holotype of this species was destroyed in Berlin, and "no material fitting the description of this species has been found."

Extinct with non-herbarium record: This category describes when all specimens of an extinct plant species have been destroyed, but visual representations of that species still exist, such as a painting, illustration, or photograph. For example, The Field Museum's Type Photograph Collection contains digitized images of 71,000 negatives of types that were photographed by J. Francis Macbride before the types were destroyed at the Botanical Museum Berlin-Dahlem

COURTESY OF SMITHSONIAN INSTITUTION

UNITED STATES NATIONAL HERBARIUM
Fragment of specimen removed for genetic analysis (phylogeny) 13 Mar 2006
det. Danica Harbaugh, UC Berkeley

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UNITED STATES NATIONAL HERBARIUM

The Last Piece of Evidence

The starkest example of a collector knowing that a species is about to go extinct can be seen on a specimen of *Santalum fernandezianum* (shown above). This tree, commonly known as Chile sandalwood, was endemic to the Juan Fernández Islands off the coast of Chile. It was overharvested over a century ago for its aromatic wood. When Carl Skottsberg collected a specimen from this tree in 1908, he knew he was looking at the living dead. In his penmanship, he writes, "Branch from the last tree." This specimen is the last piece of evidence that this tree ever existed.

At times, the collector is so certain that a species is about to go extinct (or already has) that when they give the plant a scientific name, they'll use a form of "extinct" in the new name. An inspection of the International Plant Names Index (IPNI) finds 13 instances in which a plant's name contains the Latin *extinctoria, extinctorium,* or *extinctoriformis.* It should be noted, however, that in instances in which this is found, the reference is to describe the plant's morphology as to be "fire extinguisher-like" as in the look of a candle- or wick-snuffer. So, surprisingly, these plant names did not refer to the potential demise of the species.

In contrast, three plant names contain the Latin *extinta* or *extinctus. Gasteranthus extinctus,* for example, is a species that was given its dramatic specific epithet by L.E. Skog and L.P. Kvist. The authors write, "all four collections come from ... [a] forest [that] has been totally cleared, likely causing the extinction of this species" (Skog and Kvist 2000: 67). Things take a strange turn two decades after this species was given the *extinctus* name. During a hunt for rare and threatened species, *Gasteranthus extinctus* was rediscovered in the wild (Pitman et al. 2022). This extant species now has to carry the baggage of an unfortunate name as long as it stays extant.

during World War II. Likewise, paintings and illustrations give evidence that a species was once extant.

Case study of an extinct species with a non-herbarium record: As the case above, Rocchetti, et al. (2022) was unable to find any digitized specimens or extant vouchers for 30 species in the herbaria that they contacted. One species on their list, *Coelogyne acutilabium* (Orchideaceae), is known only from a single cultivated plant, now dead, in the Bogor Botanical Garden. Eduard F. De Vogel described this species based on a single dried inflorescence, which he illustrated in *Orchid Monographs* (de Vogel 1992). The illustration is all that remains of this species.

Classically extinct: Extinct with a herbarium record: The category describes the most common definition of an extinct plant species: when a specimen exists that confirms the identity of a species that once existed as a living plant.

Case study of a classically extinct species: In the Rocchetti, et al. (2022) list of 361 globally extinct species, they found 190 species with specimens that did not bear seeds or fruit. One such species is *Weinmannia spiraeoides* (Cunoniaceae), which is known from a single sterile specimen collected in 1840 from Ovalau, Fiji (see image on page 42). No material on this herbarium specimen can resurrect this species.

POST-EXTINCTION

While lists have been drawn up to record which species are extinct, there are occasions when a species might be removed from that list. The removal may be due to the practical reason of rediscovery, or if the theoretical science of resurrection becomes a reality, the removal from the list will be due to the de-extinction of that species.

Rediscovered: Sometimes, conservation biologists make mistakes. Sometimes, taxonomy changes. There are cases when species once assessed as extinct have been rediscovered in their native range (Scheffers, et al. 2011) or in an ex situ facility, such as a botanic garden or arboretum. There are also cases when improved taxonomic knowledge leads to the species becoming a synonym of an extant species. In these cases, extinct species are rehabilitated and removed from the list of extinct species and can then be assessed as Extinct in the Wild or extant (either as threatened or as not threatened).

Case study of rediscovery in the wild: Drone surveys on extremely remote vertical cliffs of Kaua'i conducted in 2019 documented three individuals of *Hibiscadelphus woodii* (Malvaceae), a species noted as extinct in 2011 (La Vigne, et al. 2022), but now listed as Critically Endangered.

Case study of rediscovery in a botanic garden: Abeli, et al. (2022) determined that 12 plant species once deemed to be extinct are more accurately extinct in the wild or extant in a study that used Botanic Garden Conservation International (BGCI) PlantSearch database and through contacting ex situ institutions.

Case study of taxonomic changes: *Syzygium gambleanum* (Myrtaceae) from India was listed as extinct in 1988 (Oldfield, et al. 1998). However, *S. gambleanum* (an illegitimate name) is now treated as a homotypic synonym of *S. microphyllum*, a species currently assessed as Endangered (World Conservation Monitoring Centre 1998).

Resurrected: What if we can bring extinct plants back to life? Resurrection science may seem like something of the future, but recent studies are looking into de-extinction events (Shapiro 2017; Rocchetti, et al. 2022). Ethics aside, what if a plant specimen has viable seeds on the sheet? What if the specimen has extractable DNA and that plant can be cloned? This category describes species that are classically defined as extinct, but viable seeds or extractable DNA happen to exist on a specimen sheet. Can these species be resurrected?

Theoretical case studies of resurrected species: Rocchetti, et al. (2022) identified 161 extinct species and 556 herbarium specimens that appear to have available seeds, but their viability has yet to be tested. At present is a lack of optimized germination and in vitro culture protocols for utilizing the herbarium specimens for de-extinction. Since the seeds preserved on herbarium specimens of extinct species are "precious and cannot be wasted," scientists studying these specimens are using the utmost care in testing seed vigor, dormancy-breaking, and germination performance.

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The Ghost Flowers of Ebony G. Patterson

By Kay Chubbuck

Reflecting on the fraught proximity of extinction and cultivation explored in Patterson's installation. *©New York Botanical Garden, Photographer Marlon Co, 2023*

My first physical encounter with extinction was in a museum. I was at Oxford studying the legacy of colonialism, so my supervisor encouraged me to examine the dodo at the Natural History Museum. Familiar with Tenniel's illustration in *Alice in Wonderland* of this famously extinct species of flightless bird, I imagined an imposing, feathered, taxidermized specimen. Instead, in a small vitrine, there was an isolated foot; a head, which Oxford also possesses, was not on display. I remember standing there, looking at the dodo's toes, a haunting evocation of one of the world's unique species reduced to bones.

This past summer, I was vividly reminded of the Oxford Dodo in Ebony G. Patterson's exhibit, *"... things come to thrive ... in the shedding ... in the molting,"* at the New York Botanical Garden, where I serve as Vice President for Education. In Patterson's (literally) ground-breaking installation, she explored the entangled themes of colonialism, slavery, and extinction through a variety of media. In front of the Enid A. Haupt Conservatory, the artist placed cast-foam sculptures of glittering black vultures to groom physical rifts in the landscape, while within, she surrounded a sculpture of an albino peacock—inspired by one Patterson had seen molting at the Hope Botanical Garden in Jamaica—with disembodied glass limbs that rose, gesturing, from lush plantings.

Most haunting, at least for me, was Patterson's requiem to lost plants. Running through the center of the conservatory the artist placed a series of glass flowers inspired by pressed specimens of extinct plants that she had studied in NYBG's William and Lynda Steere Herbarium during her yearslong residency. Part of the power of Patterson's display was the sheer beauty of these lost plants, each like a movie star cut down in its prime. Among those she recreated were:

greensword, *'ahinahina*
Argyroxiphium virescens
Haleakala Crater, Maui, Hawai'i
Last seen: 1945

'Ahinahina grew only on Maui, in the tropical high-altitude shrublands of the eastern slopes of Haleakala's summit and Koolau Gap. Also

known as greensword, it was part of a unique group of plants called silverswords that are found only on the Hawai'ian islands. These greenswords flowered only once every seven to fifteen years after a long lifespan. Having evolved with no protective mechanisms against grazing animals, its extinction has been attributed to the introduction of pigs, goats, and other livestock that decimated its habitat during a period of colonization.

leechleaf delissea
Delissea undulata subsp. *kauaiensis*
Kaua'i Island, Hawai'i
Last seen: 1895

Leechleaf delissea was a member of the bellflower family, with palmlike leaves and greenish-white, slightly down-curved flowers. It too grew only on the Hawai'ian islands, and was last collected along the falls of the Hanapepe River on Kaua'i in 1895. It is believed to have gone extinct both because of predation by black rats that arrived on colonizers' ships as well as habitat destruction caused by the introduction of cattle and invasive plants that took root in its environment. The last known collection is housed in NYBG's Steere Herbarium.

Palo Alto thistle
Cirsium praeteriens
Palo Alto, California
Last seen: 1901

The Palo Alto thistle, also sometimes called the lost thistle, was a flowering thistle notable for its long spines and soft, cobwebby stem. It was collected by an amateur botanist from a location in California

The artist in the Enid A. Haupt Conservatory. The culmination of a yearlong residency, Patterson's installation ran through October 22, 2023. ©*New York Botanical Garden, Photographer Marlon Co, 2023*

identified only as "Palo Alto." Although the botanist didn't include much information about the plant's habitat, contemporary scientists have theorized that the thistle grew in or near wetlands, given other native thistles' propensity for wet feet. It has not been seen since it was collected in 1901, likely wiped out by rapid urban expansion that destroyed its delicate habitat. The specimen in NYBG's Steere Herbarium is one of only two known samples in the world.

This question is important, particularly at a time when we are losing species faster than we are gaining them. The climate crisis, with its accompanying habitat destruction, is accelerating extinctions, threatening more than two million species globally. And this is just a rough accounting. Scientists have yet to document the Earth's full biodiversity—an estimated 15 percent of the world's species remain uncatalogued—meaning that the number of threatened and extinct species may actually be far greater. As Inger Andersen, Executive Director of the United Nations Environmental Program, has observed, "As far as biodiversity is concerned, we are at war with nature."

For NYBG Education, Patterson's exhibition provided a critical opportunity to teach children about this crisis in ways that were both palpable and compelling. For too many people, extinction is a concept that feels remote and abstract: it's something that happens someplace else to someone else. It's happening in rain forests of the Amazon, to the golden toads of Costa Rica, and once, long ago, to the dodo on Mauritius. Audiences don't necessarily feel like extinction is happening here, now, to us, in the United States. To inspire action, we need to make the issue feel more relevant, more immediate, more localized—because the flora and fauna that we see today may not be here tomorrow unless we take action for their conservation.

For educators, the question is, how do we make this absence palpable? How can we position something that is absent as tangible—as tactile—in order to better teach the next generation to be good stewards of our environment? How do you teach a generation that has never seen, touched, felt, or smelled an extinct species not only to grasp but to care about the

Vouchers from NYBG's William and Lynda Steere Herbarium informed the "ghost flowers" Patterson created of cloudy, translucent glass.

Top left: Herbarium voucher with flower stalk of *'ahinahina*, or greensword (*Argyroxiphun virescens*). *Image courtesy of the C. V. Starr Virtual Herbarium at the New York Botanical Garden (http://sweetgum.nybg.org/science/vh/); NY 3687072.*

Top right: Palo Alto thistle (*Circium praeteriens*). *Image courtesy of the C. V. Starr Virtual Herbarium at the New York Botanical Garden (http://sweetgum.nybg.org/science/vh/); NY 2052827.*

Right: leechleaf delissea (*Delissea undulata* subsp. *kauiensis*). *Image courtesy of the C. V. Starr Virtual Herbarium at the New York Botanical Garden (http://sweetgum.nybg.org/science/vh/); NY 546919.*

Hawaiian Types Project
ISOTYPE
Delissea undulata Gaudich. subsp. kauaiensis Lammers,
Syst. Bot. 13: 505. 1988.
W. L. Wagner
May 2001
U.S. National Herbarium
Delissea undulata Gaudich. subsp. kauaiensis (Lammers) Lammers
ISOTYPE OF Delissea undulata subsp. kauaiensis Lammers, subsp. nov., ined.
T. G. Lammers
21 March 1987.
00546919
NEW YORK BOTANICAL GARDEN
PLANTS OF THE HAWAIIAN ISLANDS
COLLECTED ON THE ISLAND OF KAUAI ALONG THE MANAPEPE
RIVER NEAR THE FALLS.
BY A. A. HELLER JUNE 24-28 1895

magnitude of the crisis? The ghost flowers of Ebony G. Patterson were an incredible opportunity to make the invisible, visible. Beyond just stunning works of art, Patterson's ghost flowers were an invaluable object lesson about what we have lost.

To help children understand Patterson's art and the extinction crisis that they represented, NYBG Education created specialized tours and workshops for schoolchildren and their teachers. For example, NYBG's GreenSchool, which has operated for nearly 50 years from within the conservatory, beneath the desert houses with their sprawling aloes and flowering cacti, offered school groups a special "Challenge How You See" tour. This journey began by asking children and their teachers to reflect on the artist's statement that "A garden is never merely a garden. A garden is a burial ground for history." Starting on the lawn with the vultures (Patterson's "cleansers of the earth"), children learned about ecosystems, about cycles of loss and regeneration, as well as decay, seasonal change, and the critical interactions needed to keep ecosystems healthy. Throughout, children were encouraged to write reflections in field journals in response to questions like:

What have you heard about extinction?
What have we lost?
What we still stand to lose?

In the house with lost plants, children were asked to "sit with the dead and learn from the dead." "What could we learn from ghosts if we could talk to them?"

These ghost flowers cast in glass—fragile, breakable, in some cases positioned intentionally too close to the path to highlight the vulnerability of their ecosystems—were meant to provoke questions about extinction and in particular the role that people play in this process. As the wall text noted in NYBG's Britton Rotunda, where the original herbarium specimens were displayed, "what does it mean to sit with, learn from, a ghost?"
©New York Botanical Garden, Photographer Marlon Co, 2023

"What can we learn from the plants that we have lost?" The tour acknowledged that *"(w)hen the last living individual of a species dies and the entire life form is lost from Earth has always been part of the natural process."* Yet children also learned that typically this process happens slowly over time—over centuries or even millennia—whereas right now, extinction is accelerating. At the end of the tour, in the GreenSchool's classrooms, children made their own physical manifestation of extinct plants out of clay, so that they could bring home tactile reminders of the plant stories they had learned, to feel connected and hopefully inspired to protect the plants of the world.

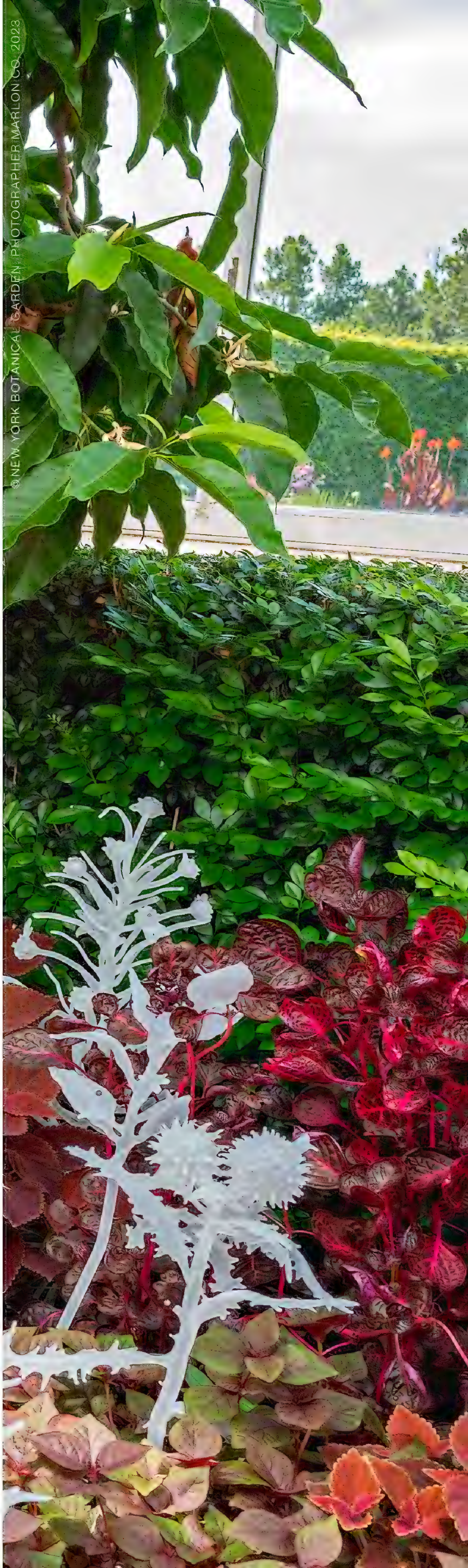
Perhaps even more significantly, Patterson's exhibit provided an opportunity for NYBG to guide teachers on how to address issues of extinction within their own classrooms. Each summer, NYBG's Professional Learning team offers an "Art of Science" course for third through twelfth grade teachers, primarily from New York City Public Schools, using the Garden to model outdoor education initiatives and nature-based learning strategies. In addition to meeting Next Generation Science Standards, these "Art of Science" courses are intended to help participants hone skills of observation and critical inquiry that they can then share with their own students as well as with teacher communities to advance science education more broadly. To help gain this wider reach, teachers are encouraged to invite friends and colleagues to their final project presentations: three-part lesson units on how to leverage cultural institutions like the New York Botanical Garden to teach children art and science.

For *"... things come to thrive ... in the shedding ... in the molting,"* teachers spent an intense week at NYBG learning about the artist and her practice as well as the plants, both living and extinct, that formed the core of the exhibition. Teachers sketched and journaled throughout NYBG, going "behind the scenes" at the Steere Herbarium and learning about the extinct plants that inspired Patterson's ghost flowers. Notably, the "Art of Science" course covered Patterson's exhibition as a whole; it was not exclusive to the extinction crisis. And because climate education is not yet included in Next Generation Science Standards, Patterson's ghost flowers served more as a jumping off point for plant adaptations, which is included in the state curriculum, than extinction per se. Viewed through this lens, Patterson's recreation of the *'ahinahina* became a means to spotlight an extraordinary plant journey. Likely descended

from seeds that arrived in Hawai'i stuck to the feet of migratory birds, silverswords have persisted in high elevations despite shallow root systems that make them vulnerable to grazing livestock and wandering tourists. They are poached by plant collectors, outcompeted by invasive plants, and preyed upon by invasive species. Yet in 1989, botanists discovered hybrids of the lost *ʻahinahina* and another closely related silversword, meaning some of this extinct greensword's DNA survives, despite all the many challenges. Teachers were encouraged to use such plant narratives to teach children about resilience—in themselves, in the plant world, and our planet as a whole—to inspire hope that what we learn about the extinction crisis has the potential to guide our future, not just memorialize our past.

Today, botanical gardens, once founded to be living cabinets of curiosity, are havens of biodiversity. We preserve species; we speak for plants. Scientists may not yet be able to reverse the collateral damage of the so-called "Age of Exploration," to bring back species from the dead like the *ʻahinahina* of Hawai'i, the lost thistle of California, or the famous dodo bird. But we can better protect and steward the Earth's remaining species—and teach the next generation how to do the same. To be successful in this mission, we need opportunities for object-based learning to make the invisible, visible and the absent, palpable. We need physical examples like the ghost flowers of Ebony G. Patterson so that children, teachers, and their families can better grasp that our Earth is a wonderland in need of our protection. To do this, we need audiences to look, really look at the extinction crisis. We need to give people tools to peel back their learned complacency in order to position the extinction crisis as relevant and immediate and connected to their own experiences. As Patterson has stated in interviews, the trick is to get people to look, not just see: "Looking requires thought, it requires engagement, it requires awareness, it requires inquiry, it requires presence," the artist has said. Looking at Ebony G. Patterson's ghost flowers in the Enid A. Haupt Conservatory, it was hard to ignore the absence of these extraordinary plants.

KAY CHUBBUCK *is vice president for education at New York Botanical Garden*



While we were fearing it, it came

By Emily Dickinson

While we were fearing it, it came –
    But came with less of fear
Because that fearing it so long
    Had almost made it fair.

There is a fitting – a Dismay –
    A fitting – a Despair –
'Tis harder knowing it is due,
    Than knowing it is here.

The trying on The Utmost
    The Morning it is new
Is terribler than wearing it
    A whole Existence through.

EMILY DICKINSON *(1830–1886) unsigned poem [n.p., 1874?]. Transcription based on MS Am 1118.1 (11), Houghton Library, Harvard University; and Amherst Manuscript #522, Amherst College. Via Emily Dickinson Archive, http://www.edickinson.org, accessed April 30, 2024.* *CC BY-NC-ND 3.0.*

VISUAL ESSAY

In Search of Thoreau's Flowers

Charles Davis, Marsha Gordon, Emily Meineke, Leah Sobsey, and Robin Vuchnich

> *"The earth is not a mere fragment of dead history, stratum upon stratum like the leaves of a book, to be studied by geologists and antiquaries chiefly, but living poetry like the leaves of a tree, which precede flowers and fruit— not a fossil earth, but a living earth...."*
>
> Henry David Thoreau, *Walden; or Life in the Woods*

Transcendentalist writer, philosopher, and naturalist Henry David Thoreau is one of the most studied American thinkers of the nineteenth century. We took him as the genesis for our interdisciplinary multimedia exhibition, *In Search of Thoreau's Flowers: An Exploration of Change and Loss,* because his process of collecting and studying plants was the prevailing citizen science of the day. His notated pressed plant collection—housed at the Harvard University Herbarium—dates to the mid-nineteenth century. Thanks to its digitization and open-access status, scientists and artists can use these materials to study and reflect upon the impacts of climate change in the Walden Pond area.

In Search of Thoreau's Flowers is a multilayered attempt to convey both the beauty and the decline of the natural world. Reanimation lies at the center of the exhibit: using digital technology allows us to bring long-dead specimens back to life. The exhibition features digitized animations of Thoreau's pressed plants, original cyanotype and gold leaf works inspired by Thoreau's collections, and a rotating sample of Thoreau's original pressed plants.

In *"This is, and no mistake"*—the immersive data visualization by Robin Vuchnich—Thoreau's entire collection of 648 digitized specimens is organized into one view, illuminated in a floor-to-ceiling immersive theater. Using historical and present-day data points, the visualization is color-coded to reveal which sheets contain plants in decline. By visually collapsing the space between Thoreau's time and the present, an astonishing reality is revealed: over half of the plants represented by Thoreau's specimens are now in decline. As we approach a time when these plants may only be seen preserved in museums or digitized online, we can think of these as digital ghosts of the landscape Thoreau once revered and documented.

Leah Sobsey's photo-based work explores the natural world through archives and taxonomies with an experimental, materials-based approach grounded in historical photographic processes and plant-based printing.

Opposite: *Blue-bead Lily* from the "Fall of the Leaf" series by Leah Sobsey. Original cyanotype on glass backed in 23K gold; text from Thoreau's journals.

A plant Thoreau collected, now in severe decline.

In homage to nineteenth-century photographer and botanist (and Thoreau contemporary) Anna Atkins, Sobsey utilizes the historical photographic process of the cyanotype in conjunction with contemporary modes of production, including digital technology. *"The Fall of the Leaf"* portraits use the specimens most severely declining at Walden Pond. The handmade cyanotypes on glass are backed with 23-karat gold leaf to pay tribute to the plants and preserve what has been, and is being, lost. The reflective gold surface acts as a mirror: the viewer and surrounding world are reflected in the artwork.

In *"The Dispersion of Seeds,"* Sobsey uses all 648 digitized Thoreau specimens to create the exhibition's wallpaper. Playing off Vuchnich's data visualization, the dark cyan color represents specimens in decline, while the light cyan represents specimens surviving and/or thriving. The tiled wallpaper integrates digital and analog technology as a tool for sharing ideas about climate change.

"Leaves Contain Multitudes" features *Eurybia macrophylla* (bigleaf aster), one of the many plant specimens from Thoreau's collection that is declining today. Thoreau's meticulous journal entries, combined with more recent data, indicate that plants flower on average over one week earlier today than they did in the 1850s. Moreover, those species that haven't modulated their flowering time with warming temperatures have experienced striking declines: nearly 27% of the species observed by Thoreau have been locally extirpated, and another 36% are incredibly rare.

Thoreau's specimen of *Cornus rugosa* (roundleaf dogwood), used in the background of *"Could Thoreau Have Imagined a World in which a Bee Could No Longer Find Its Flower?"* provides a striking example of the consequences of our rapidly changing climate. Roundleaf dogwood and related species in the Cornaceae are not able to adjust their flowering time in relation to temperature as much as other taxa. Now, species in this family are experiencing precipitous declines in the region. The specific mechanisms linking flowering responsiveness to rarity is still unknown; however, one possibility is that plant species may fall out of sync with their pollinators, especially if insects, such as bees, are better able to adjust to warming temperatures than the flowers themselves.

Since climate change spans human generations, the effects can feel imperceptible. Declining specimens from Thoreau's herbarium shine a light on the effects of climate change through animated data visualizations. Visitors must contend with loss, while also encountering the plants' beauty, even while they exist solely in a pressed, desiccated state. Thoreau's collection allows us to imagine how science, art, and the humanities can speak to each other in a way that engages audiences of all ages. We aim to inspire reflection, provoke awe, and raise awareness all at once.

This Is and No Mistake by Robin Vuchnich.

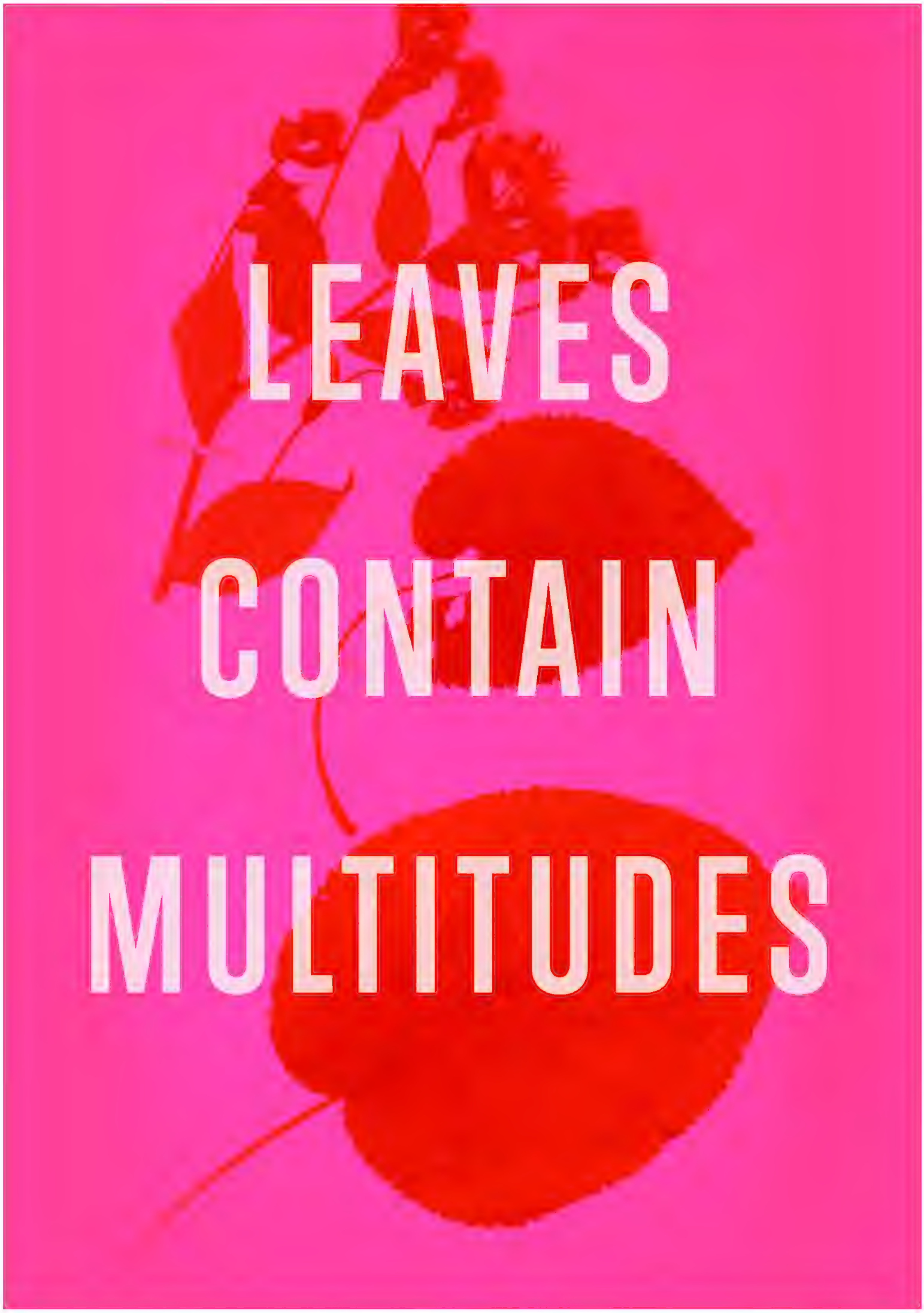
Data visualization of Thoreau's herbarium: sheets that contain plants in decline, in dark blue, represent over half of the collection.

CHARLES DAVIS *is professor of organismic and evolutionary biology & curator of vascular plants, Harvard University Herbaria.* MARSHA GORDON *is professor of film studies in the English Department at North Carolina State University.* EMILY MEINECKE *is assistant professor of urban landscape entomology at the University of California, Davis.* LEAH SOBSEY *is associate professor of photography and director of the Gatewood Gallery at the University of North Carolina, Greensboro.* ROBIN VUCHNICH *is an assistant professor of the practice at North Carolina State University.*

IN SEARCH OF THOREAU'S FLOWERS: AN EXPLORATION OF CHANGE AND LOSS *opened at the Harvard Museum of Natural History in May 2022.*

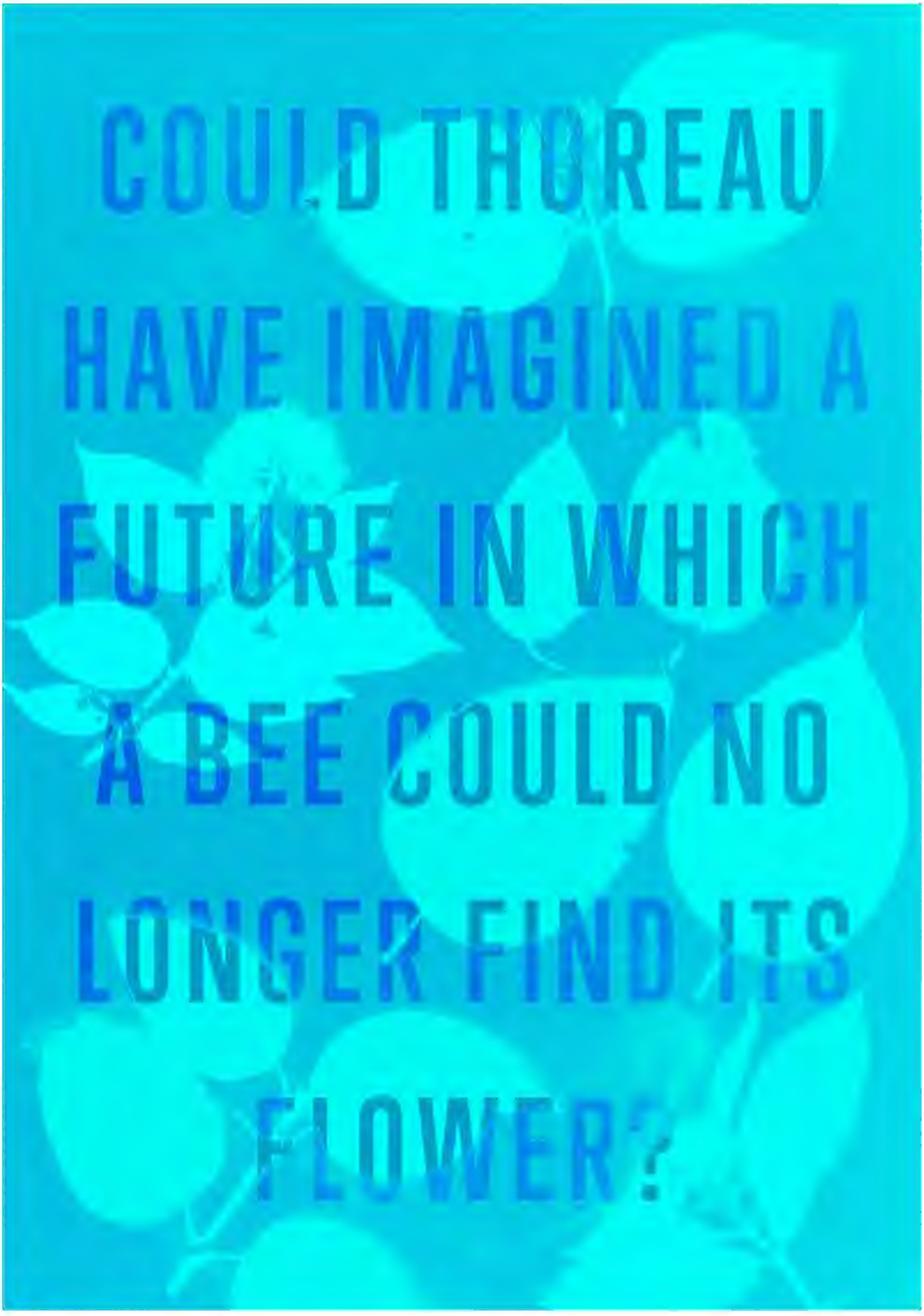
Mirrored Composition 1
by Robin Vuchnich. Digital collage of herbarium specimens.

Gatefold: *Losing Flowers*
by Robin Vuchnich. Digital collage of specimens featured in the immersive gallery projections.



Leaves Contain Multitudes by Marsha Gordon and Robin Vuchnich. Digital collage.

Eurybia macrophylla (bigleaf aster), another plant Thoreau collected, is now in severe decline.



Could Thoreau Have Imagined a Future?
by Marsha Gordon and Robin Vuchnich.
Digital Collage.

When Thoreau collected once-plentiful *Cornus Rugosa* (roundleaf dogwood), could he have imagined its scarcity in the twenty-first century?

Propagations

LANDSCAPE VIEW

Narratives at the Margins of Extinction

By Rosetta S. Elkin

1 Most people can name an extinct animal or two, proudly citing wooly mammoths or passenger pigeons. But how many people can name extinct plant species? Plants seep into our lives, our stories, sheltering, scattering, nourishing, and also haunting our world. A solid retort to the question would be to name wild silphium, which may be the first recorded case of plant extinction in human history. It is certain that silphium plants were no longer described in European and Arab texts after the 1st century CE. Writing for *Heritage* magazine in 2022, Lisa Briggs and Jens Jakobson of the British Museum observe that "Any direct evidence for the organic remains of silphium was likely lost in the soil heap of time."[1] And yet the soil heap of time might just be a momentary resting place for future generations of silphium.

2 Extinction is such a finite word. It evokes annihilation or destruction; to put out, go out, or die out. The term seems insufficient in relation to plants due to its singular, enclosed implication. Singularity inevitably lends itself to lists and tallies, an anxiety over individual species that can be counted, brought to us by an incomplete fossil record, the maze of millions and billions of years, and vivid models of lost vertebrates. We can only define what is extinct in stable terms.

3 Picture a sleepy afternoon along the fringing marshes of Georgia, the air swarming with peregrine falcons riding thermals down the coastline. It is October 1765, and two travelers are botanizing along the southern reaches of the Altamaha River. This is where John Bartram and his son William famously discovered a small grove of trees with white flowers that bore "beautiful good fruite."[2] And so begins the story of *Franklinia alatamaha*, and its circuit across the horticultural world, from Bartram's pocket, to Kew gardens, and back.[3] Franklin trees are available for purchase at most garden centers, while heritage trees can be appreciated along the paths of many arboreta. This shrubby-looking tree is famous for the moniker *extinct in the wild*. The specimens at the Arnold Arboretum are considered the oldest cultivated Franklin trees in the world, thriving under the care of generations of keepers. This shared heritage leaves out why Franklin trees are not thriving across the creeks and coves of the Altamaha in the 21st century.

4 When the study of extinction and the efforts to prevent it turns towards the living, it is often called conservation, since the signature cause of species loss is land transformation, which is to say, habitat loss, a process associated with the production of agricultural fields, plantations, roads, railways, mining, and other consequences of urbanization. We know that extinction accelerates when changes in the environment outpace the ability of a species to adapt; habitat is fragmented more quickly than most populations can adapt, pushing species to the edge of their range or devastating them altogether. These stories leave leave out more than they include, however, because when land is "transformed," it undergoes systematized violence that extends to all species, including our own. Consider that much of the world's biodiversity now survives in landscapes and seascapes maintained by Indigenous or local communities.[4] A society that trades in accounts of lost species is a curious one, striving for narrative fixity, and the same

Illustration by Jason Holley

kind of stability that leads me to question the limits to the term "extinction" in relation to plant organisms. Perhaps it is hard to name an extinct plant because the word "extinction" slips so easily into a single story of loss. As Thomas King bravely stated; "you have to be careful with the stories you tell. And you have to watch out for the stories you are told."

5 On the morning of May 25, 2022, a straggly looking tree caught the attention of a research team, its trunk scarred by fire, its thin canopy submitting to a fungal infection.[5] At the time, *Quercus tardifolia* (Lateleaf oak) was thought to be extinct, after a decade or two of failed attempts to find populations across Big Bend National Park in Texas, a landscape roughly the size of Rhode Island. Despite the bigness of the park, *Q. tardifolia* is still considered a single-site endemic, a species limited to a specific location. A year into the discovery, skilled collectors from arboreta and botanic gardens found a few more isolated trees, offering more signs of persistence despite a scarcity of acorns.[6] Acorns do not survive well in a traditional seed bank; a buried cache from an ice age-ground squirrel, meanwhile, yielded a living plant from the oldest living seed, 30,000 year old tissue living with the desiccated remains of a mammoth, bison, and wooly rhinoceros.[7] Those who measure life by counting the boxes and the losses rarely have a metric for persistence. *Q. tardifolia* thwarts the opposition of extinct or alive, reminding us that land is more than property and plants are more than commodity.

6 What is extinction in the present tense? Can plants show us the way towards a livelier extinction, suggesting extinction as a verb? *Extincting* could neither be owned, nor labeled. Rather, *extincting* would be the search for evidence of earthly processes that includes humans; an activity of bootprints and volcanic eruptions, of storytelling and submerged coasts, of humanity arduously represented in the accretions and intervals of instability that mark the durations of the great chapters in Earth's history. *Extincting* moves us beyond the reach of scientific tallies, loss valuations, ecological nostalgia, and conservation policy. It allows us to actively participate in the present, and offers an inclusive vocabulary. It makes extinction a cultural issue.

Can plants show us the way to a livelier extinction, suggesting extinction as a verb?

7 The remarkable Franklin tree prompts a return to the abundance of ecological intrigue that awaits visitors to the Altamaha River. Despite its status as wholly thriving in cultivation, what remains extinct is the habitat that sustained it: the buried Pleistocene rhythms, the deep biotic associations of the marsh and lagoon terraces. I imagine Franklin trees rising from what was once a sand-covered ridge between wet and dry terraces, making the most of a marginal landscape slowly warming since the last glaciation. The subsequent transformation of the land during the colonial era was comparatively violent, as Creek and Cherokee societies were forcibly removed. When the social geography changed, so too did the coastal hydrology: canals and irrigation trenches were dug to make way for plantation estates and fields of rice and cotton cultivation.[8] Most of these changes are still visible beneath the canopy, evidence of what Aldo Leopold calls "a world of wounds." Land transformation is not so sudden, it turns out, but unfolds across a cultural environment that drives social, hydrologic, biotic and climate change. This is what it means to be extinct in the wild.

8 *Extincting* is, in part, about teaching and learning from the cultural conditions that normalize ecological violence. When extinction is activated as a cultural issue, it begins the intellectual work of honoring the struggle to get there, as a way to break apart extinction as a finite, closed term. That humans have impacted the land, seas and climate, is not simply a means to apply the historical record to infer past human activities, but can be rethought as a way to celebrate other species' survival, even survival at the edge. Ignoring existing struggles beyond the singular label

"extinction" can be, paradoxically, an undermining of habitat destruction, because it overlooks the incomplete effort to make sense of it in the present. The margins are precisely what activates attention, as single-site endemics are admired in the wild, just as their spirited ancestors thrive in horticultural worlds.

9 Terry Tempest Williams wrote that the Endangered Species Act is an act of love. I would add that it is an act of love for the late twentieth century, a time of categorical fixity, a century that demanded transactional lines to tally and record species loss. We must ask what kind of love it is, when the Act rejected the addition of *Quercus tardifolia* to the Texas list in 2009.[9] Up to one-sixth of the tree species found in the continental United States are on the margins of extinction, yet only a handful enjoy federal protection under the U.S. Endangered Species Act. At the same time, plants represent over half the species listed under Act, yet their human stewards, keepers, and explorers receive less than five percent of total funding for endangered-species recovery. The cost of such care is significant: Imagine looking for a thirty-foot tree in an 880,000 acre park. Or rather, imagine that it takes an act of protection at the scale of 880,000 acre to conserve a species.

10 For their fennel-like appearance and thick roots, silphium plants were tentatively reclassified as *Ferula* spp., although quarreling over labels stretches across the centuries between its reference as Greek silphium by Theophrastus and its decline as Roman silphium by Pliny the Elder. Classification aside, both naturalists include a lengthy survey of what is lost when humans love a plant death: the sap or juice called 'laser' was a popular flavor for cooking, the resin was an expensive medicine for cures from cough and sore throat to cardiac maladies, but it was most valued as an effective contraceptive. Its wild seed was foraged and recognized for nourishing sheep that produced tender meat, and its stalk was valued at its weight in gold.[10] All of this while silphium flourished spontaneously as a little herb that resisted agricultural cultivation and was primarily collected in the wild.[11] Taken together, humankind did not just lose a plant by wasting its habitat, commodifying its gifts, or grazing it to decline; we lost a familiarity with wildness. Plants that thrive on the margins as buried seed, in botanical collections and in hiding across conservation lands are those that ask us to rekindle our wild selves, and participate in the extincting process, not as as contributors to demise but as agents of survival.

Rosetta S. Elkin is a designer and author. She is the academic director of the Landscape Architecture Program at the Pratt Institute, founding principal of Practice Landscape LLC, and a research associate at the Arnold Arboretum.

NOTES

[1] Briggs, Lisa, and Jens Jakobsson. "Searching for Silphium: An Updated Review." *Heritage,* vol. 5, no. 2 (2022) pp. 936–55 (939).

[2] Plummer, Gayther L. 1977. "'Franklinia Alatamaha' Bartram Ex Marshall: The Lost 'Gordonia' (Theaceae)." *Proceedings of the American Philosophical Society* 121 (6): 475–82.

[3] Del Tredici, Peter. "Against All Odds: Growing Franklinia in Boston." *Arnoldia* 63:4 (2005), pp. 2–7. See also Plummer, cited above.

[4] There are numerous reports, and varying statistics that bring to light this reality, for instance: Reyes-García, Victoria, et al. "Recognizing Indigenous Peoples' and Local Communities' Rights and Agency in the Post-2020 Biodiversity Agenda." *Ambio,* vol. 51, no. 1 (2022) pp. 84–92.

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[11] Briggs, (937).

SMALL WORLD

Saving Seed, Growing Knowledge

By Elinor Breman

I have always been fascinated by seeds: their beauty and variety of shape, form, and function. What makes them even more remarkable is that they are travelers in both space and time. A seed represents new life—each seed containing the genetic resources to produce a new plant, from a tiny watermeal (*Wolffia* spp.) to a towering redwood (*Sequoia sempervirens*). The seed contains the food reserve needed to enable growth, and a protective outer layer to withstand the elements. As one colleague has put it, they are the next generation sent off with a packed lunch and a coat.

For over two decades, the Millennium Seed Bank Partnership (MSBP) has been at the forefront of global plant conservation through the study, conservation, and use of seeds of some of the world's rarest and most important plant species. Described by Sir David Attenborough as one of the world's most ambitious conservation projects, the MSBP is managed by Royal Botanic Gardens, Kew (RBG Kew). It has been working with a global network of partners in almost 100 countries, helping to build national collections of seed material whilst ensuring they are made available to research and conservation communities. The majority of these collections are stored in the country of origin and duplicated to the Millennium Seed Bank (MSB), housed in the heart of the Sussex countryside at RBG Kew's Wakehurst gardens. Through this work, over 50,000

Illustration by Helen Musselwhite

species have been saved from extinction.

The MSBP is not alone in collecting and banking seeds to preserve them for current and future use. While the MSBP focuses on wild origin material, our agricultural systems are based on seed saving, and a global network of genebanks conserving agricultural plant diversity also exists. Established by the Norwegian government and managed by the Nordic Genetic Resource Centre (NordGen) in collaboration with the Crop Trust, this network supports the only other global seed bank, the Svalbard Seed Vault, a safety deposit for the world's crop diversity.

But why do we need to conserve plant germplasm in this way? Surely maintaining plants in their natural habitats and crops in our landscapes is better than hiding seeds away in underground vaults? Unfortunately, the rate of environmental change means that many plants are unable to adapt on a relevant timescale—and many of the threats that are facing plants (land use change, over-exploitation, invasive species, pollution, and climate change) do not respect the borders of even the best-kept protected areas.

The rate of environmental change means that many plants are unable to adapt on a relevant timescale.

As all life depends on plants and the fungi that support them, it is critical that we halt the tide of extinctions—"reversing the red," as the International Union for the Conservation of Nature describes the effort—not only because humans are the root cause of the losses, but because our very existence depends on having plants to provide our foods, materials, medicines, and to deliver regulating, supporting and cultural ecosystem services. Work presented in the State of the World's Plant and Fungi report in 2023, a document contributed to by 200 scientists from 102 institutes in 30 countries and published by RBG Kew, showed that 45 percent of flowering plant species are potentially threatened with extinction. This is more than 500 times faster than the extinction rate for plants before humans existed. Epiphytes and orchids were identified as the most threatened plant forms, and islands and archipelagos (such as Hawaii, Madagascar, and Borneo) were shown to be hotspots for predicted extinctions. Endemic species also face a greater risk of extinction, by dint of their limited distribution. There are currently 221,399 single-country endemics, found nowhere else on Earth. Less than half have had their extinction risk assessed, or are central to national biodiversity conservation plans in their home country. In addition, 77 percent of undescribed species are predicted to be threatened with extinction—meaning they could be lost before they are even known to science.

This research is important not only in highlighting the extent of the threat, but also in helping us plan to prevent it. Armed with lists of known threatened species, or those predicted to be threatened, we can target these species for collection before they are lost. However, this does not mean that we should ignore more common species, whose populations have yet to decline and so hold greater genetic diversity than tiny populations of species that are fast approaching extinction.

Seed banking works on very basic principles. Drying and freezing seeds in airtight containers can extend their lifespan for tens to hundreds of years—providing opportunities not just for our generation, but for generations to come. It also means a large amount of genetic diversity can be stored in a small space (compared to growing so many individual plants in a botanic garden or arboretum)—with thousands of seeds in each collection that provides thousands of possibilities to regrow that plant, study its properties and better understand how to help protect it. Holding collections in two locations (e.g. the country of origin and the MSB) provides a safety net should a natural or manmade catastrophe overtake a seed bank - this is referred to as duplication of a seed collection. The underground vault at the MSB has been designed to last for 500 years, to enable new cold rooms to be added as existing ones become full, to withstand a plane crash, to detect radiation (and cut off the air supply to the vault if it is), and with automated fire and flood protection built in. This seemingly apocalyptic planning to me highlights the value and importance of

the life that is stored here—some of it now irreplaceable as it has become extinct in the wild.

As the technology is relatively simple for storing seeds from plants that can withstand drying and cooling (those with orthodox seeds)—it can be practised anywhere in the world. Over the years, RBG Kew has developed simple solutions, from providing "portable dry rooms" (airtight containers containing a desiccant, like silica, charcoal, or rice) to helping governments build state-of-the-art facilities for seed banking and research.

At the MSB, we work with a variety of partners, from other botanic gardens, to forestry and agricultural gene banks, to universities and research institutes, as well as government bodies and NGOs. Knowledge transfer is at the heart of the global partnership. This includes training in the latest techniques to collect seeds from wild populations through to managing them in the seed bank and undertaking germination tests. It also invovles technology transfer, from providing help and advice on equipment through to designing a new seed bank facility. Through knowledge transfer, we can help ensure that seed collections are held to the highest possible standards, meaning the quality of collections is high and viability is correspondingly maximised. It also involves capacity-building beyond the techniques needed to keep the seeds alive by providing an opportunity for practitioners who often work in isolation to come together and be part of a wider community with shared interests and shared difficulties. Peer-to-peer learning and support is one of the most sustained ways of moving practice forward.

One of the most remarkable things about using seed banks to help prevent extinction is the amazing global community of practitioners that it has created over the past decades. The achievements of the MSBP would not have been possible without the dedicated and passionate people all over the world who want to ensure that nature has a place in all our futures. For me, working with and learning from this amazing community is a great privilege, and I am continually learning from our parnters be they in botanic gardens and seed banks, or restoration practicioners or plant breeders. They come from all walks of life, and all corners of the globe, united by their desire to work for a place for plants to survive.

Through knowledge transfer, we can help ensure that seed collections are held to the highest possible standards.

The work of this far-flung community faces daunting technical challenges to the long-term preservation of viable seed. There are limits to the plants that can be stored in traditional long-term conservation seed banks (-20C, 15% equilibrium relative humidity). "Exceptional species" are now widely acknowledged to have four types of exceptionality that threaten their ability to survive and thrive under these conditions: they may not produce seeds; they may not withstand drying; they may not withstand freezing; or they may have such complex dormancy issues that we could not easily create a new plant from the seed. Cryopreservation offers possibilities for some of these species, but tends to require a unique, research-intensive protocol for the banking

Elinor Breman is head of the Seed Conservation Team at Royal Botanic Garden Kew's Millennium Seed Bank.

of each different species. Luckily for us, and the plants, research has shown that for most plant groups the proportion of species that can survive under traditional seed bank conditions is above 90%. There are, however, some categories of plants that have higher proportions of unbankable species—and this includes those considered critically endangered by the IUCN and global tree species (only about 65 percent of which are bankable).

Another limitation is that conservation seed banks tend not to regenerate their collections in the way that agricultural genebanks do. We do not grow out a set amount of collections on a regular cycle in order to collect more seed for storage but prefer to re-collect from the wild where this is possible. There are many reasons for this, one of which is purely practical—with over 40,000 species from all across the world banked at the MSB, many of them trees, there is no possibility of regenerating seed from the majority of our collections. This has implications for the adaptability of the plants in these collections, as the genetic diversity of collections is held in stasis in the bank while the environments in the outside world are changing. However, recollection from the wild helps to mitigate this.

It is important, however, to stress that the MSB is a working bank—with deposits and withdrawals being made—not a static museum. For example, wild relatives of our agricultural crops have been sent to pre-breeders around the world to investigate their properties useful to adapting agriculture to climate change. In the UK, the interrupted brome (*Bromus interruptus*) designated extinct in the wild, has been re-introduced using seeds from our collections, and seedlings of the creeping willow (*Salix repens*) were passed to Butterfly Conservation to support their efforts to conserve the dark bordered beauty moth, whose caterpillas feed exclusively on this species.

By bringing together such a wealth of plant diversity in one relatively easily accessible location, the options for supporting those interested in working on seeds (be they artists, scientists, conservationists, or others) is truly transformational. In addition to safeguarding collections, their duplication or sharing between seed banks also increases opportunities for their use. The form of use in partner countries varies depending on the type of institute partnered with the MSB, from direct use in conservation and restoration, to supporting government-led initiatives in forestry and agriculture, to research into seed longevity, propagation, and environmental tolerances. The seeds stored at the MSB tend to be used by an international community for research, education, and display, while maintaining a base collection as a last resort. The only caveat is that seeds cannot be used for commercial purposes—for that, a request would need to go back to the country of origin.

Seedlings of the creeping willow (*Salix repens*) were passed to Butterfly Conservation to support their efforts to conserve the dark bordered beauty moth.

Building up the case for seed banking as a conservation tool and raising the profile of this technology at the national, regional and international scale means that seed banking is now recognised as a cost-effective means of protecting plant diversity. However, collections of trees in a seed bank are not a forest, nor a suite of herbaceous seed collections a wildflower meadow. We still need to focus our effort on conserving habitats, but with time running out for many plant species in their natural habitat, seed banking is an insurance policy we must continue to use.

Collecting Herbarium Specimens

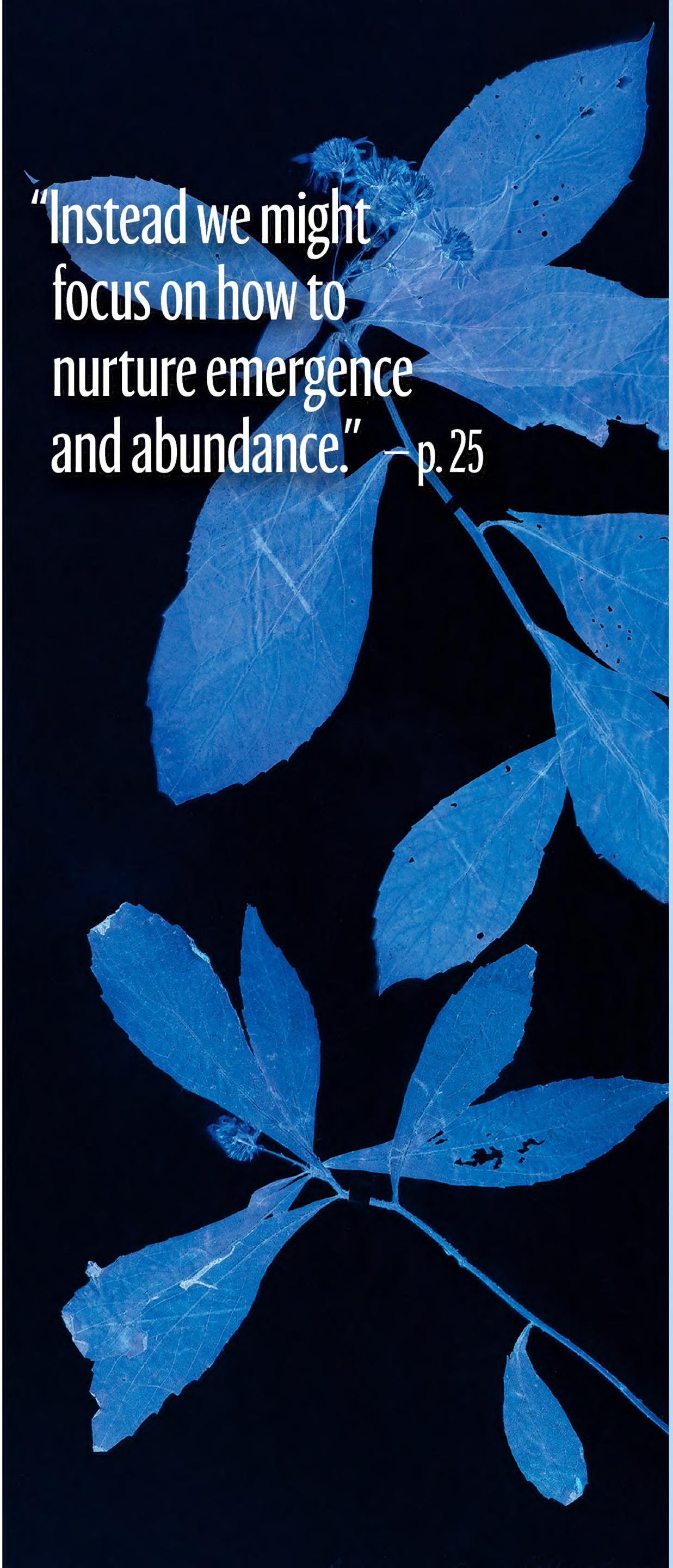
By Devika Jaikumar,
Curatorial Assistant

120,853
Vouchers in the herbarium

91
Specimens collected in 2023

The Herbarium of Cultivated Plants spans much of the Arboretum's history; its oldest vouchers date back over 100 years. Additions to this record are ongoing: from spring to fall, I arm myself with pruners and a plant press, venturing out into the landscape in search of plants for the collection. Timing is crucial—we want specimens with "reproductive structures" (flowers, fruit, or cones), and each species produces these at different times. I carefully take an optimal cutting, making sure not to harm the live plant in the process, and place the specimen into the plant press. Equally important are the collection notes, which will accompany the cuttings in the herbarium vouchers. The collection information indicates what the entire plant looked like, what the cutting looked like at collection, the plant's growing conditions, and any other pertinent information for a researcher to know. Once the cuttings are pressed and dried, it's off to the herbarium to mount the specimens onto paper, creating the final herbarium voucher. These vouchers and the associated collection information are recorded in the arboretum's plant collections database BG-BASE. Finally, the specimens find their home in the cabinets of the herbarium.

Photograph by Jamila dePeiza-Kern



"Instead we might focus on how to nurture emergence and abundance." — p. 25

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